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Vol. V JUNE, 1918 No. 6

BOSTON SOCIETY OF CIVIL ENGINEERS
FOUNDED 1848

PROCEEDINGS

PAPERS IN THIS NUMBER.

"The Sanitary Control of Swimming Pools." Stephen DeM. Gage.

Discussion of Economy in the Design of Concrete Buildings.

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MINUTES OF MEETINGS.

BOSTON, May 15, 1918. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, Charles M. Spofford, at 8 o'clock.

There were 68 members and visitors present.

The record of the last meeting was read and approved.

The Secretary reported for the Board of Government the election of the following to membership in the grade of Member: Almon Isaac Gauthier, Frederic William Haley and Harry Matthew Steward.

The President announced the death of Frank S. Hanf, a member of the Society, who was killed in action in France, April 28, 1918. He was second lieutenant in the 2d U. S. Engineers. By vote, the President was requested to appoint a committee to prepare a memoir. The committee appointed consists of Messrs. Theodore P. Perkins, Frank B. Rowell, and Charles H. Restall.

The President called attention to a circular which he had sent out to the membership of the Society asking for contributions to a fund for the 602d Engineer Regiment, now at Camp Devens and soon to go to France, and called on Capt. George C. Danforth of that regiment for further information as to its needs for such a fund.

Captain Danforth said that it was not only a new regiment but a new type of regiment, for which a call has been sent across, and there are only a few weeks instead of eight or ten months in which to get ready.

He also said in part: "I have been asked once or twice why the government does not provide some of the things that we are especially in need of, — a band for instance. That I do not know. The army regulations has always provided for a band for its one regiment, or part of a regiment, of engineers, and it speaks of 'the Engineer Band.' There are now some two hundred thousand of us and still it authorizes 'the Engineer Band.' And we need other things which require a fund, partly in the line of equipment, but principally for recreation.

"I have heard it said that war is a thing of knowledge and calculation. It is not. War, so long as it is at the risk of men's lives, is a thing of instinct and psychology and what a man *does* at the front depends much on the mental attitude that he brings there. That in turn depends on what he gets when he is back of the lines and has time to stop and think. Discipline, of course, plays its part. The man is drilled to obey commands without question, but we want more than that. We need the band and some means of giving the men a foot ball or base ball game; something to keep their minds off the unpleasant things, to keep them mentally fit.

"As I said before, I think the matter is well covered in the circular. We need about five thousand dollars, and if we cannot appeal to engineers for it I do not know to whom we can go. We have no time to try and interest people by the usual methods. Our appeal is to you."

The President then introduced the speaker of the evening, Mr. Stoughton Bell, who was chairman of a committee appointed some years ago to devise a more systematic method of real estate assessment for the city of Cambridge.

Mr. Bell, with the aid of plans and diagrams, described very fully the system of real estate assessment which was recommended by the committee and which was put in force last year.

At the conclusion of his address a most interesting discussion followed, in which Mr. James J. Casey, chairman of the Board of Assessors of Cambridge, Mr. Albert B. Fales, first assistant tax commissioner of Massachusetts, Mr. Frank O. Whitney, chief engineer of the Street Laying-Out Department of Boston, and others, took part.

By a unanimous vote, the thanks of the Society were extended to Mr. Bell for his kindness in presenting to the Society in so clear and interesting a manner the new departure in real estate assessment.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, May 1, 1918. — A special meeting of the Sanitary Section was held Wednesday evening, May 1, 1918, at 8.00 o'clock, in the Society's Library, Tremont Temple, Boston.

Dr. W. W. Peter, of Shanghai, China, secretary of the Joint Council on Public Health Education of the National Medical Association, the China Medical Missionary Association, and the Young Men's Christian Association, gave an address on "Health Education in China." The address was practically an English translation of a lecture which Dr. Peter has been giving all over China. It was illustrated with lantern slides and many devices for displaying statistics.

No business was transacted.

Forty-one members and visitors were present.

HENRY A. VARNEY, *Clerk.*

APPLICATIONS FOR MEMBERSHIP.

[June 15, 1918.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

BRUNO, ALPHONSO, Brighton, Mass. (Age 38, b. Boston, Mass.) Educated in Boston public schools, graduating from English High School in 1897. Since that time has been actively connected with construction of engineering projects; from 1906 to date, member of firm of Bruno & Petitti, contractors of public works, during which time has executed following contracts: Milford sewerage system and North Attleboro reservoir and dam, F. A. Barbour, Engr.; sewerage system, Attleboro, J. J. Van Valkenburgh, Engr.; sewer contract, Fitchburg, D. A. Hartwell, Engr.; sewer contract, section 10, Passaic Valley sewerage system, Newark, N. J., W. M. Brown, Engr.; Sections 102 and 103, Wellesley extension, Metropolitan Sewer, F. D. Smith, Engr.; is charter member of American Society of Engineering Contractors, New York. Refers to F. A. Barbour, W. M. Brown, H. H. Chase, E. S. Larned, Leonard Metcalf and F. D. Smith.

ROLL OF HONOR.*

ADDITIONS.

BEAN, THOMAS W. Co. C, 301st Engrs., Camp Devens, Mass.

EBERHARD, WALTER C. Chief Quartermaster, U. S. N. R. F., Co. 18, Naval Aviation Detachment, Mass. Inst. of Technology, Cambridge, Mass.

HARWARD, EDWIN D. Lieutenant, 714 Mills Bldg., Washington, D. C.

STEARNS, RALPH H. Lieutenant, U. S. N. R. F., Bureau of Yards and Docks, Room 752, 1317 F St., Washington, D. C.

REVISIONS.

BALCH, WILLIAM H. Captain, Engrs., U. S. R., Am. Ex. Force, France.

BROWN, H. WHITTEMORE, 2d Lieutenant, Engrs., U. S. R., Am. Ex. Force, France.

COFFIN, SAMUEL P. 1st Lieutenant, Engrs., N. A., Ry. Trans. Corps, Camp Merritt, N. J.

DURHAM, HENRY W. Captain, U. S. R., 23d Engrs., Am. Ex. Force, France.

HASTIE, FRANK B. 303d Engrs., Camp Dix, Wrightstown, N. J.

RICHARDSON, EDWARD B. Major, 101st Field Artillery, Am. Ex. Force, France.

RICHMOND, CARL G. 1st Lieutenant, E. R. C., Co. A, 602d Engrs., Camp Devens, Mass.

TOSI, JOSEPH A. Sergeant, D Co., 301st Ammunition Train, Camp Devens, Mass.

WELLS, EDWARD P. Cadet, U. S. A. School of Military Aeronautics, Carruthers Field, Fort Worth, Texas.

WESTON, ARTHUR D. 1st Lieutenant, 26th Engrs., O. C. E., Am. Ex. Force, France.

WHITNEY, RALPH E. Captain, Sanitary Corps, National Army, Surgeon-General's Office, Washington, D. C.

LIST OF MEMBERS.

ADDITIONS.

HALEY, F. WILLIAM.........................1 Pine Ave., Haverhill, Mass.
MOORE, RUFUS R...................316 Huntington Ave., Boston, Mass.
STAFFORD, EARL.............185 Devonshire St., Room 410, Boston, Mass.

CHANGES OF ADDRESS.

BOAS, BENJAMIN...care Monks & Johnson, 78 Devonshire St., Boston, Mass.
EBERHARD, WALTER C...................138 Poplar St., Roslindale, Mass.

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* Members who are in the service and have not yet reported that fact to the Secretary are earnestly requested to do so, stating branch of service, rank and military address.

Ellsworth, Samuel M. .... 117 Adams St., Braintree, Mass.
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LIBRARY NOTES.

Book Review.

State Sanitation — A Review of the Work of the Massachusetts State Board of Health, Vol. II, by George Chandler Whipple, Harvard University and Mass. Inst. of Technology; for sale by Harvard University Press, Cambridge, 1917.

Reviewed by Harrison P. Eddy.*

Every engineer who has followed closely the work of the Massachusetts State Board of Health has long realized that papers, reports and researches of great value were being lost sight of in the vast quantity of material published during the last half century. It is therefore with a feeling of relief that Professor Whipple's "State Sanitation — A Review of the Work of the Massachusetts State Board of Health" is welcomed, the second volume of which has recently appeared.

The members of the Boston Society of Civil Engineers, particularly, will be pleased to see as the frontispiece of this volume, an excellent likeness of one of its honorary members and a past president, Frederic P. Stearns, who was chief engineer of the board for a period of nine years, during which some of its most important work was accomplished.

The first part of this volume is devoted to a reproduction, in whole or in part, of thirty-four papers of exceptional interest and value. Many of these articles describe original researches in sanitary science, and it is safe to say that there are few, if any, governmental boards in this or other countries, which have produced so fine a collection of valuable contributions to the literature of public sanitation.

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* Metcalf & Eddy, Consulting Engineers, 14 Beacon Street, Boston, Mass.

To mention here all of these articles would consume more space than is warranted in a book review. However, one cannot neglect to call attention to a few which stand out prominently because of the sound principles enunciated and the original investigations described. Pollution of Ice Supplies, 1889, probably from the pen of Dr. Walcott; Suggestions as to the Selection of Sources of Water Supply, 1890, by Mr. Stearns; Typhoid Fever in Its Relation to Water Supplies, 1890, by Mr. Mills, who gave so generously of his time and effort as the engineer member of the board for nearly thirty years; Microscopical Analysis, 1890, by Dr. Sedgwick; The Interpretation of Water Analyses, 1892, which rings true after a quarter of a century, by the late Dr. Thomas Drown; Some Physical Properties of Sands and Gravels, with Special Reference to Their Use in Filtration, 1892, by Mr. Hazen; Examination of Sewer Outlets in Boston Harbor and of Tidal Waters and Flats from Which Shellfish are Taken for Food, 1905, by Mr. Goodnough; and A Review of Twenty-One Years' Experiments upon the Purification of Sewage at the Lawrence Experiment Station, 1908, by Messrs. Clark and Gage, are among the most notable, and should be familiar to every engineer who is at all interested in the broad field of sanitary engineering.

The latter portion of the volume is devoted to brief abstracts of scientific articles and reports, which have appeared in annual publications of the board. They give, in the short space of about sixty pages, a " bird's-eye view " of voluminous documents which cover hundreds of pages in the original publications. By scanning these abstracts the reader can gain a good idea of the scope of the work done from 1870 to 1914.

Professor Whipple is to be congratulated upon his success in selecting and presenting so illuminating a guide to this storehouse of valuable literature devoted to public sanitation.

RECENT ADDITIONS TO THE LIBRARY.

U. S. Government Reports.

Abstracts of Current Decisions on Mines and Mining, May to August, 1917. J. W. Thompson.

Determination of Unsaturated Hydrocarbons in Gasoline. E. W. Dean and H. H. Hill.

Digest of Publications of Bureau of Standards on Electrolysis of Underground Structures Caused by Disintegrating Action of Stray Electric Currents from Electric Railways. Samuel S. Wyer.

Forestry and Community Development. Samuel T. Dana.

Gypsum Products: Their Preparation and Uses. R. W. Stone.

Geologic Structure in Cushing Oil and Gas Field, Oklahoma. Carl H. Beal.

Gold, Silver, Copper, Lead and Zinc in Arizona in 1916. V. C. Heikes.

Gold, Silver, Copper, Lead and Zinc in California and Oregon in 1916. Charles G. Yale.

Initial Priming Substances for High Explosives. Guy B. Taylor and W. C. Cope.

Methods for Increasing Recovery from Oil Sands. J. O. Lewis.

Ore Deposits of Northwestern Part of Garnet Range, Montana. J. T. Pardee.

Oil and Gas Possibilities of Hatchetigbee Anticline, Alabama. Oliver B. Hopkins.

Progress Reports of Experiments in Dust Prevention and Road Preservation, 1916.

Production of Lumber, Lath and Shingles in 1916. Franklin H. Smith and Albert H. Pierson.

Relative Resistance of Various Hardwoods to Injection with Creosote. Clyde H. Teesdale and J. D. MacLean.

Use of Permissible Explosives in Coal Mines of Illinois. James R. Fleming and John W. Koster.

County Reports.

Essex County, Mass. Engineer's Report for 1917.

Municipal Reports.

Brookline, Mass. Annual Report of Water Board for 1917.

Concord, N. H. Annual Report of Water Commissioners for 1917.

Dover, N. H. Annual Report of Water Commissioners for 1917.

Fall River, Mass. Annual Report of City Engineer for 1917.

Leominster, Mass. Annual Report of Water Commissioners for 1917.

New York, N. Y. Report of Bureau of Buildings, Borough of Manhattan, for 1916.

Reading, Mass. Annual Report of Water Commissioners for 1917.

Springfield, Mass. Annual Report of Water Commissioners for 1917.

Taunton, Mass. Annual Report of Water Commissioners for 1917.

Wellesley, Mass. Annual Reports of Water and Municipal Light Commissioners for 1917.

Miscellaneous.

Unit Fiber Strains in Rails per Moving Wheel, Recorded and Elucidated by Stremmatograph. P. H. Dudley. Gift of author.

LIBRARY COMMITTEE.

Vol. V JUNE, 1918 No. 6

BOSTON SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications

THE SANITARY CONTROL OF SWIMMING POOLS.

BY STEPHEN DEM. GAGE,* MEMBER OF BOSTON SOCIETY OF CIVIL ENGINEERS.

(Presented before the Sanitary Section, December 5, 1917.)

SOMETHING over seven years ago, while the speaker was connected with the Massachusetts Board of Health, we were asked to advise the operators of two swimming pools as to what methods to employ to ensure a water which should be both clean and safe for bathing. Both pools were new and up to date, and were equipped with filters for repurifying the water. Although we had little practical knowledge of swimming pool operation as such, we had had a wide experience in the operation of the various methods of water purification at the Lawrence Experiment Station, and approached the problem with the feeling that a few weeks' experimental work to tune up the filters and get them working properly would probably solve all difficulties. We soon discovered that there are a number of factors involved in the sanitary operation of a swimming pool which do not have to be considered in problems connected with the purification of water for other purposes, and our experiments with these two pools were continued for nearly a year before the operating methods had been adjusted to yield satisfactory results.†

As the fact that these studies were in progress became known to other swimming-pool operators, other requests for advice were received, and the investigation was extended to other pools. In each case we found different conditions, different equipment, and a different problem which required a somewhat different method of solution. It became evident then that until pools and equipment should be standardized, the sanitary control of each swimming pool would be an individual problem, and that even could we standardize pool and equipment we would still be unable to standardize the bathers.

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* Chemist and Sanitary Engineer, Rhode Island State Board of Health.

† Clark and Gage, 1912 Report Massachusetts State Board of Health, pp. 346–367.

During the past year we have been engaged in an investigation of the various swimming pools in Rhode Island, in which we have endeavored to obtain as complete information as possible as to all details of construction, equipment, methods of operation, etc., which might in any way affect those sanitary conditions. As my part of the program to-night I propose to discuss various aspects of the swimming-pool problem, using the Rhode Island pools as an illustration of conditions which are more or less general throughout the country. Throughout the investigation we have received the hearty coöperation of the swimming-pool operators, who realize that they have been working in the dark and welcome any criticism or suggestion which will enable them to improve conditions or make their pool more attractive. It should be clearly understood that conditions as we found them are reported for purposes of illustration, and in certain instances those conditions have been or will be greatly improved as the problems of the different pools are worked out and the best method of operation to suit individual conditions is determined.

Swimming Pools and Disease.

Each bather carries a certain amount of pollution into the pool no matter how thoroughly he may have attempted to wash himself before entering, and there is always a possibility that infectious material may thus be introduced and transmitted to other bathers. The list of diseases which may be transmitted by these means includes not only the usual water-borne diseases, — typhoid, dysentery and other infections of the alimentary canal, — but also a number of diseases which do not have to be considered in ordinary water-supply problems. In a number of instances, epidemics of colds, sore throat, and similar infections have been reported among users of swimming pools, and in one instance a number of cases of pneumonia occurred among the members of a swimming team. Infections of the ears and of the eyes in certain cases have also been attributed to use of swimming pools.* There also appears to be a general fear in some quarters that skin diseases and venereal diseases may be transmitted through this means, and during the past summer the pool at the Army and Navy Y. M. C. A. at Newport was closed on account of a feeling that it might become a medium for infection of this nature. The number of authentic cases of infection through swimming pools is extremely small, when the large number of persons using such pools throughout the country is taken into account, and from all evidence at hand the danger of transmission of disease through this medium must be considered relatively slight.

Nevertheless it should be clearly recognized that such danger may exist, and that the sanitary control of swimming pools is essentially a public-health problem which should come under the jurisdiction of the public health authorities. In California and some other western states, all bathing establishments, swimming pools, etc., are already under state supervision. The methods for properly controlling the purity of the water in a swimming pool require expert chemical and bacterial knowledge which the usual swimming-pool operators cannot be expected to have, and the placing of such knowledge at their disposal through state supervision would in many instances lead to improvements in operation by which the possibility that the pool might become a medium for infection would be reduced to a minimum.

Bathing Load.

The relative proportion between the number of bathers using a swimming pool and the capacity or volume of that pool has an important bearing upon the sanitary condition of the water. To state the question baldly, a swimming pool may be likened to a big tub in which a considerable number of persons take a bath in the same water. Obviously, if the pool is small and the number of bathers large, the contamination of the water will be much greater than if the reverse is true. In certain instances this relationship has been expressed by assuming the water to be equally divided among the persons using the pool in a given time. This method of expression permits a comparison between the probability of contamination of different pools, but as the results are in inverse ratio direct comparison is somewhat difficult.

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* All references to recorded cases of infection from swimming pools are omitted here, as a complete bibliography of the subject will be found elsewhere in this Journal. An unreported epidemic of conjunctivitis occurred among users of a swimming pool in a neighboring state about five years ago.

For purposes of comparison, I have used a somwehat different method of expression, which for lack of a better term I have called the " Bathing Load." This expression, which gives values in direct proportion to the probability of pollution, is obtained by dividing the number of bathers using the pool by the volume of water in thousand gallons. As the attendance usually varies considerably on different days of the week, and as pool usage, cleaning, disinfection, etc., are usually run in weekly cycles, the weekly bathing load is probably the most convenient term for general purposes, although daily, monthly or yearly bathing load figures may be useful in special cases. Experience elsewhere has shown that the amount of pollution introduced into the water is influenced to a certain extent by the age, sex and degree of personal cleanliness, of the persons using the pool. With equal requirements as to preliminary bathing, women will contaminate a pool more than men and children more than adults. From any available data, however, it is impossible to determine just what corrections should be applied to the computed bathing load for different classes of bathers, and for general purposes the uncorrected figures are sufficient.

The fourteen indoor pools in Rhode Island vary in capacity from 9 500 gals. to 75 000 gals. Three of these pools have capacities of over 50 000 gals., and six others have capacities of 30 000 gals. or over. The normal attendance at these pools varies from about 90 per week to about 1 200 per week, and the normal weekly bathing load varies from 2.0 to 24.0. The capacity, average attendance and normal weekly bathing load for each of the Rhode Island pools are shown in Table 1.

TABLE 1.

CAPACITY, BATHING LOAD, ETC., OF RHODE ISLAND SWIMMING POOLS.

	Dimensions, Feet.				Capacity. Gallons.	Bathers per Week.	Weekly Bathing Load.	Average Days Operated without Refilling.
	Length.	Width.	Depth.					
			Max.	Min.				
Brown University*.......	75	25.0	7.50	4.5	75 000	450	6.0	120
Pawtucket Boys' Club....	70	25.0	6.25	3.5	65 000	130	2.0	5
Providence Y. M. C. A.*..	60	21.5	10.67	3.0	50 000	1 200	24.0	105
Newport Y. M. C. A.*....	40	30.0	6.00	4.5	45 000	600	13.3	110
Pawtucket Y. W. C. A.*...	42	16.0	7.00	3.5	30 000	87	2.9	310
Woonsocket Y. M. C. A.* .	40	20.0	7.00	3.0	30 000	240	8.0	160
U. S. Naval Training Station (3 pools)..........	40	20.0	7.00	5.0	30 000	135	4.5	1
Pawtucket Y. M. C. A.*...	35	21.0	6.50	3.5	28 000	600	21.4	45
Newport Army and Navy Y. M. C. A.*..........	45	20.0	6.00	2.5	28 000	300	10.7	65
Moses Brown School*.....	38	14.0	6.00	4.0	21 000	325	15.5	80
Aborn Street Baths.......	25	18.0	5.67	4.9	18 000	88	4.9	14–21
Lundin Baths............	20	16.0	4.00	3.9	9 500	75	7.9	3–7
State Sanatorium†.......	170	45.0	4.50	1.5		580		1

When the bathing load is large, more care and attention is necessarily required to keep the pool clean and the water in a sanitary condition than where the load is small. At the Pawtucket Boys' Club, where the pool receives no attention between the weekly refillings, the fact that the water does not become badly contaminated may be attributed to the very low bathing load. At times, of course, the number of bathers using a pool will greatly exceed the normal, and at such times a variation in the cleaning or purification practice may be necessary to properly care for the extra load.

After the declaration of war, in 1917, the various Y. M. C. A. pools were thrown open to enlisted men, and there was a large increase in the daily attendance. A most interesting but rather disastrous incident resulted from this free bathing privilege while the Rhode Island troops were being mobilized in August. During the extreme hot weather which marked the week of August 4, the men were marched in continuous relays to the Providence Y. M. C. A. for a bath and swim. The records show that during this week more than 12 000 bathers entered the pool, and the bathing load jumped to over 240, or more than ten times the normal load. While it had been possible to keep this pool in a cleanly condition with a greatly increased number of bathers throughout the early summer, the purification system was entirely inadequate to handle this enormous load, and it became necessary to close the pool for cleaning and refilling at a time when it was extremely desirable that it should be open for continuous use.

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* Pools operated by continuous repurification method.

† Outdoor pool with continuous flow.

Design and Construction.

Swimming pools should be so designed that there is shallow water at one end, for timid bathers or beginners, and water of sufficient depth at the other end for a person to dive without danger of striking the bottom. The size or capacity of a pool should be planned with some reference to the number of bathers which it is expected to serve. If the pool is to be operated on the continuous repurification plan, the inlets and outlets should be so located that there will be a proper circulation through the pool at times when the water receives no mixing from the movements of bathers. Even if the pool is designed to be operated on the fill-and-draw principle, unless a practically inexhaustible supply of water is available at low cost, it should be so arranged that a repurifying system can be installed later if it is found desirable to change the method of operation. The type of filters to be used should be carefully selected to ensure proper purification and ease of operation, and the filters, circulation pumps, and piping systems should be of sufficient capacity to provide for any emergency. The design and construction of a swimming pool, therefore, is essentially an engineering problem for the solution of which a thorough knowledge of hydraulic and sanitary engineering is required.

The variation in shape and arrangement of some of the Rhode Island pools is shown in Figs. 1 to 9 inclusive. In these sketches the vertical scale is double the horizontal scale, and the

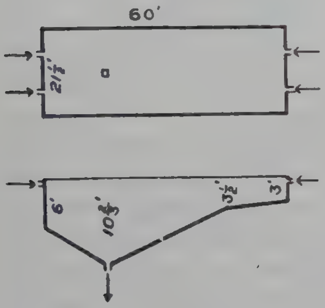

Fig. 1.

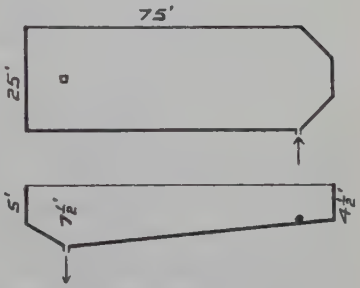

Fig. 2.

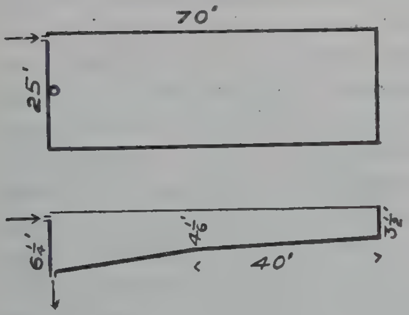

Fig. 3.

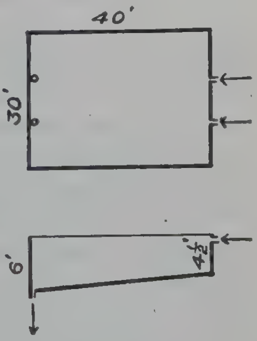

Fig. 4.

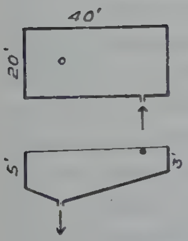

Fig. 5.

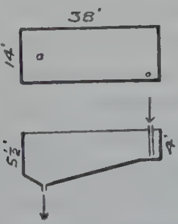

Fig. 6.

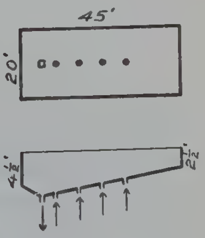

Fig. 7.

Some Rhode Island Swimming Pools.

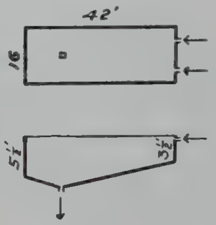

FIG. 8.

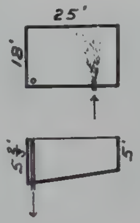

FIG. 9.

RHODE ISLAND SWIMMING POOLS.

slope of the bottom of the various pools is thereby considerably accentuated. The location of the inlets and outlets are shown by the arrows, which fly with the current. While in many cases pools have been constructed with the bottom sloping from one end to the other, as in Fig. 4, the usual practice is to slope the bottom from both ends to an outlet located about ten feet from one end, and frequently to provide a considerable area of shallow water with comparatively flat bottom. The object of such design is, of course, to provide both deep and shallow water and at the same time to cut down the construction cost and reduce the volume of water required for filling. The Pawtucket Boys' Club pool (Fig. 3) was designed primarily for the use of young boys, and it will be noted that shallow water is provided for about half the length. A somewhat smaller shallow area, with slight slope, is also to be observed at one end of the pools at the Providence Y. M. C. A. (Fig. 1) and the Moses Brown School (Fig. 6). The plan of the large pool at Brown University (Fig. 2) has been criticized somewhat severely by the swimming instructor, as, while the semi-octagonal shaped end is very effective architecturally, it materially reduces the number of bathers who can be started at one time in a swimming match.

In only two of these pools (Figs. 1 and 4) are inlets and outlets so located that a reasonably good circulation of the water can be obtained. At the former pool the outlet is located at some distance from the deep end, but there are two inlets at each end of the pool which can be throttled if necessary to maintain a proportional distribution of the entering water. Theoretically, the arrangement of inlets and outlets shown in Fig. 4, with two inlets equally spaced at the surface of the shallow end and two outlets similarly spaced close to the wall at the deep end, should give a more uniform circulation of the water through the pool than any of the other designs illustrated.

The pool at the Pawtucket Boys' Club (Fig. 3) was designed to be operated on the fill-and-draw principle. As long as this pool continues to be operated in this manner, the location of inlets and outlets is immaterial. As this pool is already equipped with filters it could be changed into a continuously operated pool at small expense, but with the present arrangement of inlet and outlet a proper circulation of the water could never be obtained. With inlets and outlets located as in Fig. 8, although there is probably a good circulation throughout the greater part of the pool there is probably a considerable volume of dead water at one end when the pool is not in use. With the designs shown in Figs. 2, 5 and 6, there must necessarily be a short circuit from inlet to outlet with very little mixing of the water in the greater part of the pool other than that caused by bathers.

A peculiar arrangement of inlets and outlets is to be noted in the pool at the Newport Army and Navy Y. M. C. A. (Fig. 7). The jet effect of the water entering through the four inlets in the bottom of the pool undoubtedly causes some mixing at those points, but it is very doubtful if this mixing is as thorough as the designer intended to produce, and there is probably much dead water in the pool. A rather interesting attempt to maintain a semblance of circulation in a poorly designed pool was found at the small pool at the Aborn Street Baths. This pool has a combined inlet and outlet in one corner, with an overflow pipe near the outlet by which a constant water level is maintained. From a water jet on one side a spray is thrown over a portion of the surface. The amount of circulation obtained by this device is probably not very great, but the spray is said to be very popular with the bathers.

There should be a broad walk extending entirely around the pool, with a slight pitch to a drain connecting directly with the sewer, in order that dirt, etc., may not be washed into the pool. This is the construction at all except two of the Rhode Island pools. At the Moses Brown School there is an elevated walk above one side of the pool with no drainage, and the other walks drain into the scum gutters. At the Providence Y. M. C. A., the walks pitch toward a shallow gutter near the edge of the pool, which drains through outlets directly into the recessed trough beneath. The walks around the pool, and especially the rounded edge of the pool, should always be corrugated or of rough material to prevent danger from slipping. At most of the Rhode Island pools, the edges are of smooth tile, but in a few cases rubber mats extending close to the edge are provided.

All pools, unless very small, should have steps or ladders at both ends, preferably at opposite corners. These should be constructed with rounded corners and edges and should have roughened treads to lessen the danger of accidents. It is much better practice also to have these steps or ladders recessed into the wall, thus leaving the pool entirely free from obstructions, and this is particularly desirable if the pool is to be used for water polo and other aquatic sports.

The finish or lining of the pool has an important bearing on the sanitary control. A smooth continuous surface, with rounded corners and no cracks, is most easily kept clean and therefore most desirable. Tile or enameled brick makes an excellent lining if properly set with well-filled joints. It is important that this lining should be white, or light colored, in order that the condition of the water and of the sides and bottom of the pool may be readily noted. In fact, a white lining against which any dirt is conspicuous is one of the greater incentives for the maintenance of cleanly conditions. All but one of the indoor pools in Rhode Island are furnished with a white tile lining which fulfills these requirements.

The floors and walls of the adjoining bath-rooms, toilets and dressing rooms, and also all lockers and furniture, should be vermin proof and should be constructed of impervious material to permit frequent washing and disinfection. A separate enclosure with separate entrances should also be provided for spectators.

Spit Troughs.

Spit troughs, overflow troughs, scum gutters, or wash troughs, as they are variously called, are usually built into the wall of a swimming pool on one or more sides. These troughs are intended to serve a double purpose, that of a convenient handhold for the tired or exhausted bather, and that of a receptacle into which the bather may spit, and for the slop from the pool. These troughs should always be connected directly with the sewer, and should be so designed and constructed that sputum and other matters deposited in them cannot be washed back into the pool. The water in the pool should always be maintained at such a level that there will be enough slop during bathing hours to flush the trough. In the best designs these troughs are recessed instead of projecting from the side walls in order that danger of bathers being injured by striking them in diving or during water sports may be avoided.

Five of the Rhode Island pools have spit troughs on all four sides, and four others have them on three sides. In only two pools has no provision been made for spitting. In all but three cases, however, the design of the spit troughs are faulty in that they either project beyond the side walls or are so constructed that matters deposited in them may be washed back into the pool. At two of these pools the water is maintained considerably below the proper level, in order to cut down the waste of water. This effectually prevents matters from poorly designed troughs being washed back into the pool, but it also reduces the wash water below that needed to carry those matters forward to the sewer connection.

The designs of some spit troughs are shown diagramatically in Figs. 10 to 15, inclusive. Fig. 10 represents what is probably

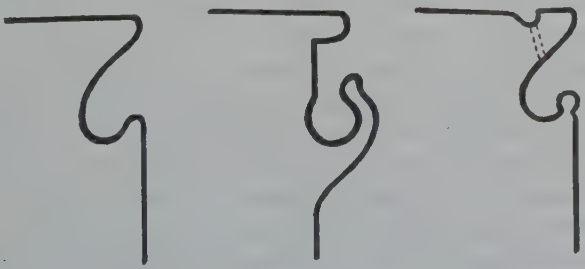

FIG. 10. FIG. 11. FIG. 12.

TYPES OF SPIT TROUGHS.

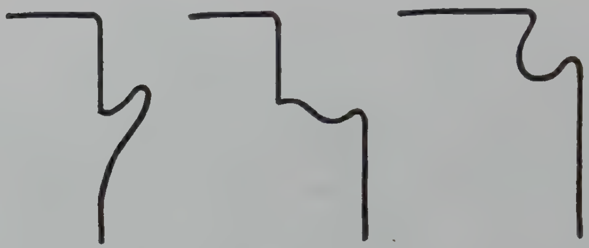

FIG. 13. FIG. 14. FIG. 15.

TYPES OF SPIT TROUGHS.

the earliest attempt to provide a place for spitting. In some instances these consisted merely of cups placed on the side walls, although generally they were built as troughs along one or more sides of the pool. As these cups or troughs projected beyond the side walls, there was more or less danger that bathers might be injured by striking against them. Figs. 11 and 12 show attempts to eliminate this fault by cutting the troughs back into the side walls. With either of these designs there was still some danger that a bather might slip on the edge of the pool and strike the edge of the trough in falling. With a design like that in Fig. 11, bathers are also likely to step down into the trough and thus disseminate sputum, etc. The type shown in Fig. 12 is less objectionable from both these viewpoints, but the water level must be kept so near the top of the pool that considerable water will be slopped out upon the side walks.

Fig. 13 shows an attempt to overcome these defects by constructing a trough which is entirely recessed in the wall. This type of trough is found on some of the pools built eight or ten years ago, and is excellent except in the one particular that the contents may at times be washed back into the pool. Figs. 14 and 15 illustrate designs intended to do away with these various objectionable features. Of the two, the writer considers Fig. 14 to better fulfill all requirements, although Fig. 15 is a popular design and has been used on a number of recently constructed pools. With either of these patterns it is still possible that the trough may be flooded by an extra large wave and apparently this fault can only be overcome by making the troughs of considerable size.

Heating, Lighting and Ventilation.

Adequate lighting must be provided so that every part of the pool may be visible at all times. For night use, indirect lighting is best, as shadows in the pool and its surroundings are avoided and the danger of accidents is reduced. It is desirable also that the pool be so located that it will receive direct sunlight during a part of the day, either from windows or skylights. Good ventilation of the room which contains the pool and of the bath and dressing rooms is essential. Even with the best ventilation it is difficult at times to prevent walls and furnishings in the vicinity of an indoor swimming pool from becoming musty, owing to the excessive humidity. Whenever mechanical ventilation is used, the incoming air should be heated, and the air ports should be so arranged that direct drafts will not strike the bathers. Either direct or indirect heating may be used, but provision should always be made for extra heat for the rooms containing the pool and the baths. Some means must also be provided for heating the water in the pool.

For comfort and to ensure the best hygienic conditions, the temperature of the pool should be about 70 to 72 degrees Fahr., and the temperature of the air should be about 75 to 80 degrees Fahr. For the control of the bacterial content of the water it would be better if an even lower pool temperature could be maintained, as even a few degrees in temperature make a tremendous difference in the multiplication of bacteria in the water. In some places it is stated that the bathers complain and the attendance falls off unless considerably higher temperatures than those stated are maintained, and as many pools are run largely to draw membership and help pay running expenses this argument must be given due weight. Hygienically considered, these higher temperatures are enervating and detrimental to the health of the bathers. The dressing rooms should be located well away from the pool and bath-rooms, should not be heated above 70 to 72 degrees Fahr. in winter, and should be thoroughly ventilated. Many a winter cold has originated from a bather going out into the winter air after dressing in a room where the temperature and humidity were too high.

All of the indoor pools in Rhode Island are lighted during the day by windows or skylights, and in nearly all cases are dependent upon these for ventilation. Steam coils or radiators are quite generally relied upon for heating. At the Lundin Baths the pool is close to the Turkish or hot room, and the air temperature is about 100 degrees Fahr. At four of the other pools the temperature of the air is kept at 80 to 85 degrees Fahr., and at the others the air temperature is maintained at 70 to 75 degrees Fahr. At all of the pools which are operated on the repurification plan the water is heated by some form of heater placed on the circulation system. At the Pawtucket Boys' Club the water is heated by the injection of live steam while the pool is being refilled, and the temperature is maintained by steam radiators in the pool. Live steam injection is also used to heat the pool at the Aborn Street Baths. The pool at the Lundin Baths is not heated, and in winter is used only as a plunge. At two of the pools the water is maintained at 76 to 80 degrees Fahr., and at the others the temperatures range from 68 to 73 degrees Fahr.

PREVENTIVE SANITATION.

Under this head are included all those measures which apply to the bathers and to the surroundings of the pool, the object of which is to promote cleanliness, to prevent the pollution of the water, to protect the health of the bathers, and to guard against accidents. Individually these numerous little details may appear to be of minor significance, but collectively they play a very important role in swimming-pool sanitation.

All bathers should be required to take a preliminary bath in the nude with warm water and soap before entering the pool. Some persons assume that, because they have had a bath that morning or some other morning, another bath is an unnecessary function, and take the preliminary bathing requirement as a reflection on their personal habits. As the patrons of a swimming pool usually come from all walks of life, this rule is necessary for the protection of all, and no discrimination can be made without the rule gradually becoming a dead letter. At those pools where bathing suits are permitted, great care must be taken to see that this bath is taken in the nude, as persons who feel that the proper procedure is to don the bathing suit before taking the shower are not nearly as rare as might be expected. The thorough cleansing of every part of the body and the subsequent removal of all soap and dirty water are of the utmost importance. The bath-rooms attached to most swimming pools are equipped only with overhead showers, the spray from which cannot be made to reach all parts of the body. The writer has repeatedly seen men and boys passing from the bath room to the pool with a distinctly visible lather under the arms and between the legs, and it is undoubtedly the case that much of the pollution carried into a swimming pool is due to the imperfect cleansing of these parts of the body. Upward sprays of the Bidet type should be provided in all bath-rooms in addition to the showers, and all bathers should be taught to use both properly. An attendant should always be present during bathing hours, to supervise the thoroughness of the preliminary baths and to exclude diseased or otherwise undesirable persons.

Whenever it is possible to enforce such a regulation, all persons should be required to bathe in the nude. At first there was much opposition to this rule when it was adopted at some of the older pools, but its great value as a sanitary measure has come to be clearly recognized at all pools for men and at a few of the pools used by women. No diseased person should under any circumstance whatever be permitted to use a swimming pool or common bathing facilities, and the great advantage of nude bathing is that it permits such persons to be recognized and excluded from the pool. Nude bathing also tends to promote a greater degree of cleanliness among the users of a pool and thus aids in preventing pollution. If bathing costumes are permitted, they should be of fast colored non-linting material and should be limited to a one-piece suit. These suits should be furnished by the management and even if owned by the patrons should be left at the bath-house and thoroughly sterilized each time used. Even when nude bathing is the rule, the use of tight fitting rubber caps should be encouraged. Much of the sediment which accumulates on the bottom of a swimming pool is composed of hair which could have been kept out of the water by the use of bathing caps. In this particular also the use of a tight-fitting suit of close material might be an advantage rather than a disadvantage, although the sanitary value of nude bathing appears to far outweigh any advantage which would be obtained in this manner.

Spitting in the pool or anywhere else except in receptacles provided for the purpose should be absolutely prohibited. Every bather takes more or less water into the mouth in swimming, and unless the "no spit" regulation is rigidly enforced this water may contain fresh, and therefore potentially dangerous, mucus recently ejected by some other bather.

It is almost needless to say that no common drinking cups, towels, common brushes and combs, should be permitted anywhere in a bathing establishment. Individual soap and towels should be supplied by the management, and the latter should be washed and sterilized each time used.

Water-flushed toilets and urinals should be conveniently located to the pool and bath-room, and every bather should be instructed to completely empty the bladder before entering the water. Some persons have a constitutional weakness which compels them to involuntarily pass urine when bathing, and every precaution must therefore be taken to prevent contamination of the pool from such sources.

Except in the case of janitors or attendants, no person in street dress should be permitted on the walks around the pool or in the bath and toilet rooms used by bathers.

A bathing attendant or swimming instructor skilled in methods of rescue and resuscitation should always be present during class hours or when the pool is used by children. All apparatus necessary for rescue and resuscitation should be conveniently placed ready for instant use. The water in the pool should always be kept sufficiently clean to permit bathers to see the bottom before diving, and when the water is drawn off all doors should be locked or roped off to prevent any one from diving or falling into the empty pool.

There should be a limit to the time bathers are permitted to stay in the water or around the pool. It is not unusual, especially during swimming competitions, to see bathers standing around the pool awaiting their turn, shivering and chattering their teeth. Swimming is undoubtedly a healthful exercise, but too long a stay in the water or in the warm, damp atmosphere surrounding the pool is debilitating and may lead to colds or more serious trouble. Thirty minutes in the pool is probably long enough for the average person, and this period should be reduced for persons not in the best of health.

The sanitary regulations and the means taken to enforce them vary widely at the different pools. At certain pools, as for example at the Providence Y. M. C. A., all bathers must pass through the shower-bath room to reach the pool. At nearly all the pools conspicuous notices are posted calling attention to the preliminary bathing requirement. In some instances talks on personal hygiene and cleanliness are given to the different gymnasium and swimming classes in which the necessity of the preliminary bath as a sanitary measure is emphasized.

At all the men's pools in Rhode Island nude bathing is the rule, and suits are permitted only during swimming competitions when visitors are present. At the Pawtucket Y. W. C. A. and at the Pawtucket Boys' Club and the Woonsocket Y.M.C.A. during the hours assigned to women, bathing suits are permitted. At both the Pawtucket Y. W. C. A. and the Pawtucket Boys' Club, the bathing costume for women is limited to a one-piece suit, and at the latter place clean suits are supplied by the management. At Woonsocket the pool is used once each week by women who bring their own suits. At the Pawtucket Y. W. C. A. and at most of the Y. M. C. A. pools, soap and clean towels are furnished by the management, usually for a small fee, and private soap and towels are prohibited. At many of the swimming pools a medical examination is required of bathers, but in the majority of cases this examination is made only when the person registers for the bathing or gymnasium classes, and only at the schools and colleges is any attempt made at regular medical supervision.

Measures for the prevention of accidents are more or less intimately connected with sanitary measures. Most of the Rhode Island pools have scum troughs on the sides, which serve as handholds for bathers, and at the pool at the Moses Brown

School, there is a handrail along one side just above the water. Shallow water should be provided at one end of the pool, for bathers who have not learned to swim. At all of the Rhode Island pools, attendants are present during certain assigned hours, but at most of these places bathers are also permitted to use the pool at other times. At all the pools, however, regulations prohibiting bathing alone are posted in conspicuous places. At the Army and Navy Y. M. C. A. pool at Newport, where there are no spit troughs or other handholds for bathers, the caution against bathing alone is printed in large letters on the wall above the pool. At some of the pools there are call bells conspicuously marked, which can be used to call assistance in case of accident.

Methods of Keeping the Water Clean.

Swimming pools may be classified as those which are refilled when the water becomes too dirty for use, and those at which filtration, dilution and disinfection are relied upon to keep the water clean and which are emptied and refilled only at long intervals. Undoubtedly the best and most cleanly method of operating a swimming pool is to empty it, thoroughly clean the sides and bottom, and refill it with fresh water every day. This is the practice with the three pools at the U. S. Naval Training Station at Newport, where an unlimited supply of salt water is available. In most cases the expense of this method of operation is prohibitive, and those pools which are operated on this principle are kept in operation for somewhat longer periods, usually until the water becomes noticeably dirty. At the Lundin Baths and Aborn Street Baths the pools are refilled at intervals of three to seven days, and of two to three weeks, respectively, depending on the number of persons who have used the pool. At the Pawtucket Boys' Club the pool is operated on a regular weekly cycle, being emptied on Sunday and cleaned and refilled on Monday. At this pool there is usually a considerable amount of sediment on the bottom by the end of the week, and at times the water has an appreciable stain and a noticeable scum on the surface.

Where the water must be taken from the city mains, the cost of the water for refilling and the cost of heating it in cold weather make this method of operation an expensive one. For example, the cost of water for filling the Boys' Club pool is approximately four dollars, and about three tons of coal are required to heat this water to the desired temperature. With coal at present prices the operating expense on account of these two items is well over thirty dollars per week in the winter. At this pool the city water is so highly colored and so much iron is stirred up in the pipes during refilling that all the water is filtered before used. Although the pool could probably be emptied, cleaned and refilled between Saturday night and Monday morning, the extra time consumed in filtering the water reduces the actual time this pool can be used to about five days per week.

The open-air pool at the State Sanatorium for Tuberculosis is in a class by itself. This pool, or artificial pond with natural earth bottom, was constructed in an old mill race. By means of head gates the water can be let into the pool at any desired rate, and by raising or lowering flashboards on the dam at the outlet practically any depth of water up to seven feet can be obtained. As operated, a constant flow of water through the pool is maintained during bathing hours. The bathing hours for children, for men and women patients, and for employees, are definitely fixed, and no mixing of the different classes of bathers is permitted. In the forenoon during the hours assigned to children, the flashboards are lowered to obtain a maximum depth of water of about two feet, but at other times a depth of between four and five feet is maintained.

Eight of the Rhode Island swimming pools are emptied and refilled only at long intervals, and repurification is relied upon to maintain the water in a cleanly condition. All of these pools are equipped with circulation pumps and filters, by which the water can be taken from the bottom, purified and returned to the pool. The equipment for repurification varies widely at the different pools. The circulation pumps at six of the pools are of the centrifugal type, varying in size from 1½ ins. to 3 ins. The other two pools are equipped with duplex plunger pumps 5 ins. x 6 ins. and 6 ins. x 6 ins. respectively. All pumps are electrically driven. Seven of the eight pools are equipped with mechanical filters of the pressure type, and one pool is equipped with open gravity filters, originally designed and operated as slow sand filters but now operated as rapid filters. Four different makes of pressure filters are represented at the seven different pools. At five of the pools the filter is in a single unit; in two cases a double unit filter is used, and in one instance a three unit filter is used. At three of the pools equipped with centrifugal pumps the capacity of those pumps was not known and could not readily be determined under the conditions which existed. At the other five pools the capacity of the pumps and filters varies from 420 gals. to 6000 gals. per hour, and the time the filters are operated varies from about one hour to twenty-four hours per day.

At seven of the pools which are operated on the continuous plan, alum is used as a coagulent whenever the filters are in operation. At the Pawtucket Y. M. C. A. alum is used only when filling the pool, and no coagulents are used at other times. Alum is also used in filtering the water for filling the pool at the Pawtucket Boys' Club. The amounts of coagulent used at the different places vary from one fouth of a grain to about four grains per gallon. At three of the pools soda is also added to the water more or less regularly, to neutralize any excess acidity caused by the use of the alum. At two of the pools where both soda and alum are used, no attempt is made to use definite amounts, and the amount actually used could not be estimated from any existing data.

As stated previously, more or less water is splashed into the scum gutters and upon the sidewalks, which does not find its way back into the pool and the replacement of this loss with fresh water is one of the factors which contribute toward the maintenance of the pool in a sanitary condition. In most cases the purifying effect of the addition of fresh water is apparently overlooked, and efforts are made to effect economies in operation by reducing the water waste to a minimum. At three of the Rhode Island pools the value of fresh water as a purifying agent is thoroughly recognized, and considerable volumes of new water are added to the pool each day.

Even with the utmost precautions to ensure the cleanliness of bathers much visible dirt finds its way into the water during bathing hours. This dirt, which consists largely of epithelium and hair, settles out upon the bottom, and unless removed at regular intervals imparts a very uncleanly appearance to the pool. More or less slime also accumulates on the bottom and side walls and has to be removed at intervals. In some of the early attempts to operate pools continuously, this dirt was stirred up in the water and the filter system was relied upon to remove it, but for reasons which will be explained later this practice was far from being a success, and in modern pool practice this dirt is now removed by mechanical means.

At many pools the bottom is cleaned by long-handled brushes or squeegees, the dirt being carefully pushed forward to the outlet through which it is discharged to the sewer or to the filtration system. This is the method employed at five of the Rhode Island pools. The disadvantage of this method of cleaning is that it can never be thorough, as some of the dirt is stirred up in the water and escapes the cleaners. At three of the pools a suction cleaner is employed to remove the dirt from the bottom, which effectually overcomes the objections to the older method. As the suction pipe has to be made of considerable size in order to obtain the necessary water velocity, the apparatus is very heavy and two men are required to operate it. Because of its weight this apparatus cannot be successfully used on the side walls, and these must still be cleaned with brushes or squeegees. It has been observed that there is less trouble from growths of green slime in pools cleaned by this method, and this has been attributed to the action of the copper worn away from the brass cleaning nozzles. The effect of copper as an algæcide is well known and may be a contributing factor, but the more thorough and more frequent cleaning which these pools receive must also be taken into consideration in the interpretation of this apparent phenomena.

At four of the Rhode Island pools the bottom is cleaned every morning, two others are cleaned every other day, and two are cleaned only once a week. At the better operated pools the side walls are also scrubbed down and any floating matters on the surface of the water are flushed into the scum gutters each

TABLE 2.

Statistics of Purification, Cleaning and Disinfection of Eight Rhode Island Swimming Pools.

	Brown University.	Pawtucket Y. W. C. A.	Providence Y. M. C. A.	Pawtucket Y. M. C. A.	Newport Y. M. C. A.	Army and Navy Y. M. C. A.	Woonsocket Y. M. C. A.	Moses Brown School.
Volume of Pool, Gallons	75 000	30 000	50 000	28 000	45 000	28 000	30 000	21 000
Times per week fresh water added	6	6	6	3	1	6	1	6
Gallons fresh water added each time	2 350	2 500	4 800	230	750	240	500	250
Type of Circulation pump	Plunger	Cent.	Plunger	Cent.	Cent.	Cent.	Cent.	Cent.
Type of filters*	G	N	H	J	M	M	M	J
Number of filter units	1	3	2	2	1	1	1	1
Hours run per day	12	10	24	1–2	6	4–6	12	9
Rate gallons per hour	6 000	2 [illegible]00	1 500	720	420	Not known	Not known	Not known
Alum used, gr per gallon	0.24	0.42	0.42	0†	3.0	Not known	Not known	. .
Soda used gr. per gallon	0	0	0	0	1.4	. . ‡	. . ‡	. . ‡
Times per week disinfectant added	2	1	2	1	1	1	1	6
Method disinfectant applied	Bag	Bag	Sol to surface	Bag	Sol. to inlets	Dry§	Dry§	Bag
Time applied	P.M.	A.M.	A.M.	A.	A.M.	A.M.	A.M.	A.M.
Hypo. added, lbs. per mil. gal.	13	33	20	9	22	. . §	. . §	24
Method of cleaning bottom	Brush	Brush	Suction	Brush	Suction	Suction	Brush	Brush
Times cleaned each week	3	6	6	1	1	3	6	6

* G — Open Gravity; H — Hungerford; J — N. Y. Cont. Jewel; M — Manning; N — Norwood.

† Alum used only when filling and decolorizing the pool.

‡ Soda occasionally added directly to the pool.

§ A handful of hypochlorite scattered over surface of pool.

time the pool is cleaned. The purification equipment, and the operating and cleaning details at these various pools are shown in Table 2.

THEORETICAL EFFECTIVENESS OF REPURIFICATION SYSTEMS.

From the foregoing we have seen that three separate agencies are employed to prevent the accumulation of dirt in the water of a continuously operated swimming pool. Two of these, filtration and the addition of fresh water, are definite quantities, and their effect individually or collectively can be expressed in definite terms for purposes of comparison. The removal of sediment from the bottom of the pool, although an important factor in maintaining the water in a cleanly condition, is not at present a measurable quantity and can be discussed only in general terms.

In the repurification of swimming-pool water by filtration, the water is taken from the pool, purified and then returned to the pool. Assuming that the purification of the water passed through the filter is complete, and this assumption is necessary for purposes of computation, the problem of determining the amount of purification accomplished in a given time becomes one of the determination of the effect of continuous dilution of the dirty water in the pool with clean water.

The effect of the successive replacement of small portions of any volume of dirty water with equal amounts of pure water may be computed by the formula —

$$D=\left(\frac{V-v}{V}\right)^{n}.$$

D being the porportion of dirty water remaining in the mixture, n the number of successive dilutions, V the total volume at the start and v the volume of pure water added each time. The proportion of pure water may then be obtained by subtraction.

This formula may be used directly to compute the purification effected by the addition of fresh water to a swimming pool, since this water is usually added at one time. A certain error is introduced when we attempt to use this formula to compute the effect of filtration on the composition of the pool, owing to the fact that the dilution is continuous rather than intermittent. If the time intervals and replacement volumes which are taken as units are sufficiently small, however, the results obtained are sufficiently accurate for all practical purposes. The combined effect of filtration and the addition of fresh water, is not, however, the simple sum of the effect of the individual filters, but must be obtained by multiplying together the proportionate amounts of dirty water remaining after the application of each factor and subtracting the product from the original amount of dirty water. It is usually more convenient to compute this combined effect separately by the use of the formula —

$$D = \left[\frac{(V-v)\ (V-v^1)}{V^2} \right]^n$$

in which v and v^1 are the volumes of pure water introduced by the respective purification methods.

Each of the preceding computations has been based on the initial amount of dirt in the water. A greater or less amount of dirt is also introduced each day, and this fact must be taken into consideration in a comparison of the effectiveness of the repurification methods. It is impossible to determine the average amount of dirt introduced into a swimming pool by any definite group of bathers. For purposes of comparison, however, it is necessary to assume some definite amount, and the simplest method is to assume that each daily increment of dirt is equivalent to the initial amount in the pool at the time repurification was started. With this assumption the proportion of the total dirt which will be found in the water at the end of any given number of days is the average of the proportions of the initial dirt remaining in the water at the end of each successive day during that period. Under these conditions, while the percentage purification steadily increases from day to day, the actual amount of dirt in the water also increases each day. If the combined purification factors are sufficiently large, a balanced condition will eventually be obtained in which the daily purification will be approximately equal to the daily pollution, and under the condition the pool could continue in operation indefinitely. If the repurification system is too small, however, the amount of accumulation of dirt will sooner or later become so large that the pool will have to be emptied. The individual and combined effect of filtration and fresh water addition at the Providence Y. M. C. A. for one week, computed on the assumption of continuous daily pollution as outlined above, is shown graphically in Fig. 16.

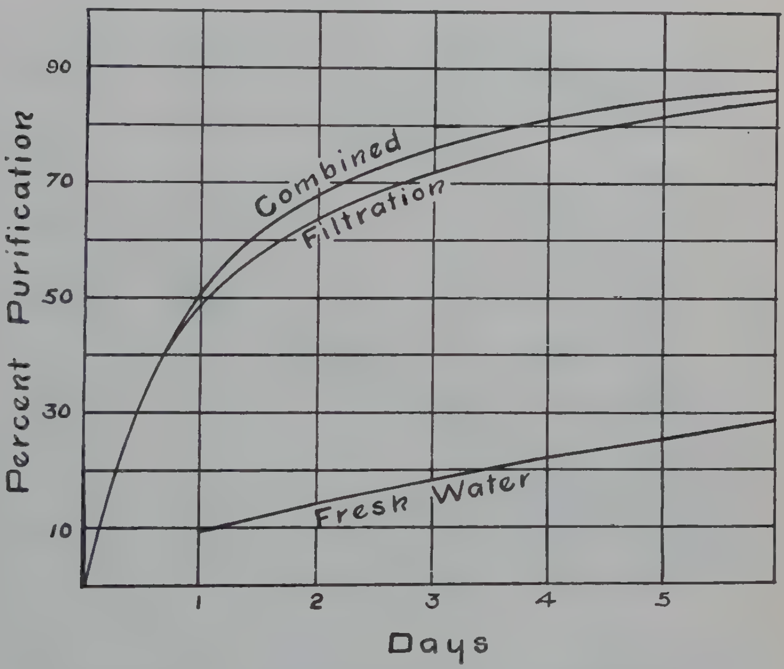

Fig. 16. Effect of Repurification Factors at Providence Y. M. C. A. Pool during First Week of Use.

If the water used for filling is of high color or contains any appreciable turbidity, it is the usual practice to keep the pool closed and run the filters continuously until such time as the water has become of satisfactory appearance. Swimming-pool operators have frequently asked why it is that it takes so long to remove the last traces of color, and why one pool can be cleaned up so much quicker than another. The answer to the first questions is to be found in the fact that the purification is by continuous dilution, and to the second that the ratio of the filter capacity to the volume of water to be cleaned up is probably very different. In Fig. 17 are shown the purification curves for one week for four of the Rhode Island pools computed on the assumption that the filters are operated twenty-four hours a day to clean up the pool. The difference in the effect of having a filter equipment of generous size and of having filters or pumps which are probably too small for the size of the pool is well shown in the diagram. At the Brown and Y. W. C. A. pools it will be observed that there is a rapid improvement in

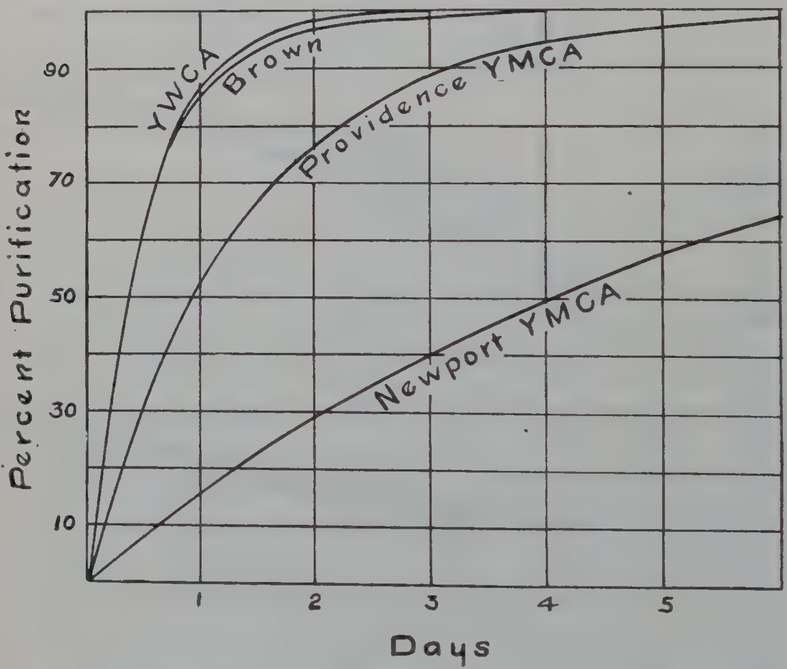

Fig. 17. Repurification at Different Pools with Filters Operated Continuously to Clean up Pool.

the quality of the water during the first two days and, that a practically complete purification would be obtained in three to four days. At the Providence Y. M. C. A. the pumps or filters are of proportionately smaller capacity and the purification curve rises more slowly. As indicated by the curve, about a week would be required to clean up this pool on starting. At the only other two pools for which we know the rate of filtration, the proportional filter capacity is comparatively small and the purification curves rise very slowly. Two weeks or more would be required to put these pools in a satisfactory condition. The curve for the Pawtucket Y. M. C. A. pool is omitted as it is practically identical with that for the Newport Y. M. C. A. pool.

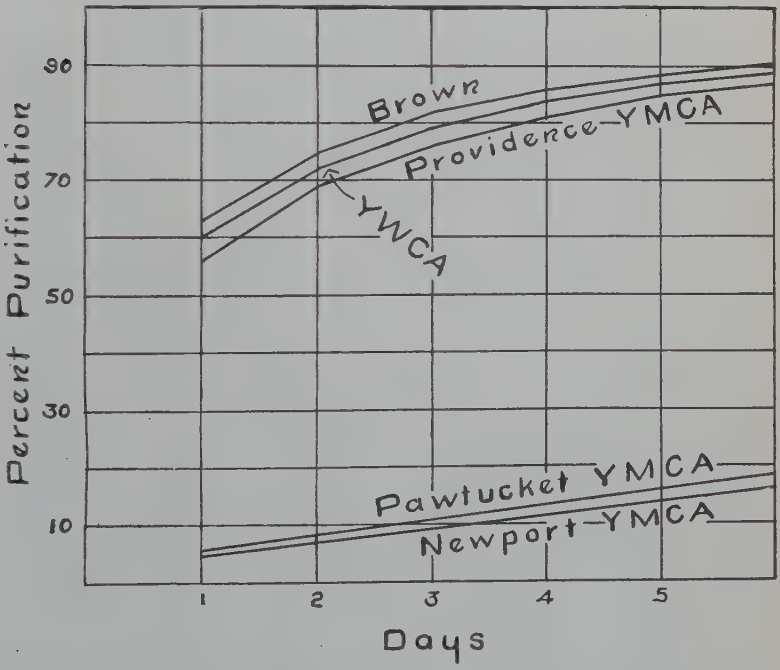

FIG. 18. REPURIFICATION OF DIFFERENT POOLS UNDER ACTUAL OPERATING CONDITIONS DURING FIRST WEEK OF USE.

In Fig. 18 are shown graphically the combined effect of these two purification factors as they are ordinarily applied at these five pools, computed on the assumption that constant daily amounts of dirt are introduced into the water by bathers. The percentage purification at the three pools which have adequate filter equipment and to which considerable amounts of fresh water are added at frequent intervals is observed to be high. On the other hand, the total purification is very low at the two pools at which filters of relatively small capacity are operated only a short time each day, and at which the amounts of fresh water are also very small. In Fig. 17 it was observed that the continuous filtration curves for the Brown and Y. W. C. A. pools were quite similar, with the Brown curve slightly below the other, while the curve for the Providence Y. M. C. A. was considerably lower than the other two. In Fig. 18 the combined purification curves for these three pools as operated are seen to closely parallel one another, with the Brown curve at the top. This reversal of position is caused by the fact that while a greater proportion of fresh water is added daily at the Y. W. C. A. pool, and the filter plants at both pools are relatively of the same capacity, the Brown filters are operated two hours longer each day. The rise in the position of the curve for the Providence Y. M. C. A. is due to the much larger additions of fresh water and to the fact that the filters are operated twenty-four hours a day. In the case of the latter pool, the limit of purification by filtration has been reached, while the other two pools still have a generous reserve which can be called upon in emergency. Continuing the computations for the five curves shown in Fig. 18 to the end of a year, we find that the purification for the Brown, Y. W. C. A. and Providence Y. M. C. A. pools would be 99.81, 99.78 and 99.76 per cent. respectively, while the purification for the Pawtucket Y. M. C. A. and Newport Y. M. C. A. pools would only be about 52 per cent. and 46 per cent. respectively. It is readily seen from these figures that with the high bathing loads at these latter two pools a rapid accumulation of pollution in the water must be expected under the present operating conditions.

DISINFECTION.

Experience has shown that it is practically impossible to control the bacterial content of the water in a swimming pool by any of the previously described processes, and at nearly all continuously operated pools some method of disinfection is employed. Hypochlorite of lime, copper sulphate, liquid chlorine, ozone and ultra-violet rays, have all been used for this purpose with more or less success. Hypochlorite is the disinfectant the most commonly employed, owing to its low cost, its ease of appliction, and its high germicidal power, and especially owing to the fact that unless used in excessive amounts it is entirely broken down in a short time and leaves behind nothing which can render the water unsuitable for bathing. Although much less potent than hypochlorite as a germicide, copper sulphate is much more effective for destroying algæ and other micro-organisms, and for this reason is of great value for the treatment of outdoor pools, and may also be used to advantage to destroy the green growths which occasionally make their appearance in indoor pools.

Ultra-violet rays, ozone and liquid chlorine are all effective sterilizing agents when properly applied to clear, low-colored waters such as are usually found in swimming pools. The chief disadvantage of each of these agents lies in the fact that it is applied only to the water in the circulation system, and for reasons discussed in the preceding chapter we can never expect to obtain a complete sterilization of the entire body of water in the pool under the conditions which ordinarily exist. In the case of ozone and ultra-violet rays, this difficulty appears to be insurmountable. In the case of liquid chlorine, however, it might be possible to obtain practically the same effect as with hypochlorite treatment if the chlorine were added in considerable excess to the water as it is returned to the pool and this overtreated water was immediately and thoroughly mixed with the other water in the pool.

At each of the eight continuously operated Rhode Island pools, hypochlorite is used as a disinfectant. The amount of disinfectant used and the method and frequency of application, however, vary widely at the different pools. At two pools no attempt is made to use definite amounts, a handful being scattered on the surface of the water. At one pool, the chemical is dissolved in water, strained, and the clear solution sprinkled over the surface; and at another a similar solution is added to the pool at the inlet from the circulation system. At the other four pools the chemical is placed in a bag and this bag is dragged back and forth through the water until the disinfectant has been entirely dissolved. The water is disinfected at five of these pools once a week, twice a week at two pools, and every day at the other pool. At one pool the treatment is applied at night, and at all the others it is applied in the morning. The amount of hypochlorite used at each treatment varies from 9 lbs. per million gallons to 33 lbs. per million gallons. The amount of disinfectant and the method and frequency of application are shown in Table 2.

Theoretically, the disinfectant should be applied each night immediately after the bathers have left, in order to immediately destroy any infectious material present in the water. As the action of hypochlorite is very rapid there should be immediate and thorough admixture with the water in the pool, and this is more successfully accomplished by the use of the bag method described above than by the use of a solution. The practice of using dry hypochlorite on the surface should be discouraged, as undissolved particles are likely to remain on the surface of the water and affect the eyes of the bathers. The amount of disinfectant employed should be sufficient to cause an effective sterilization of the water, but any large excess must be avoided or irritations of the eyes and mucous membranes may be caused.

At Brown University the operation of the pool is supervised by the professor of bacteriology, and at the Newport Y. M. C. A. the operator received occasional assistance from the bacteriologist of the local water company. Except in these two instances the operators of the various Rhode Island pools have been working completely in the dark, with no means of knowing anything as to the effectiveness of their disinfection and purification methods, and this is also undoubtedly the situation at the majority of other pools in the East. Judging from my own experience, swimming-pool operators generally would welcome expert advice and assistance if they could obtain it, and it certainly would appear that the swimming-pool problem is of sufficient importance to warrant this advice and assistance being given through supervision by the public health authorities.

Quality of Water.

For reasons which have been stated, analyses have not been made of samples from the open-air pool at the State Sanatoruim, and from the three pools at the U. S. Naval Training Station. Both chemical and bacterial analyses were made on many samples from the other Rhode Island pools although the amount of time which could be devoted to each pool was entirely too small to fully determine the effect of individual variations in operating detail. The analytical results, however, do indicate the general effectiveness of the sanitary practice at the various pools.

The conditions in a swimming pool are extremely favorable for growths of the ordinary types of water bacteria. Growths of those types which are determined at body temperature and of B. coli have also occasionally been observed in waters where the temperature conditions were similar to those maintained in some of these pools. In any interpretation of bacterial analyses of swimming-pool water, therefore, these facts must be given due weight.

Although it is highly desirable that water to be used for bathing should be of good quality, it is the opinion of many sanitarians that the standards of purity of waters used exclusively for this purpose may safely be made somewhat lower than those for drinking water. For example one writer has proposed a standard of "not more than 10 B. coli per cc.," which would permit swimming-pool waters to contain something like two hundred times as many B. coli as are permitted in the drinking waters used on trains and boats and interstate service. As to whether such a standard is both safe and fair, and whether the same standard should be applied to all waters used for bathing whether in swimming pool or at bathing beaches are questions which demand serious consideration. This much is certain, however, that if the quality of the water in our swimming pools is as good as that of our public water supplies we have at least provided a water for bathing which is inside the safety limit.

For the benefit of those who may be unfamiliar with the interpretation of water analyses, it may not be out of place to state here that owing to the limitations of our analytical methods it is not practicable to determine the presence or absence of disease-producing organisms in water. The types of bacteria which we include under the term B. coli, and for which we make tests, are not in themselves believed to be harmful, but being probably of human or animal origin they are used as an index by which we may measure the probable degree of pollution of a water.

In the case of four pools, the results of all analyses showed the water to compare favorably in bacterial quality with the public water supply of the cities in which they were located. In the case of five other pools, samples were also obtained at times which would pass our drinking-water standards, although at other times the water was not of such good quality.

At three of the pools samples taken early in the investigation showed very high bacterial counts. At two of these, Providence Y. M. C. A. and Newport Y. M. C. A., certain changes were made in the operating methods, and samples taken later were of much better quality. The pool at the Army and Navy Y. M. C. A. was closed soon after the first series of analyses were made, and subsequent samples could not be obtained. At five of the pools B. coli were found in 10 cc. of the water in occasional samples. In no case was B. coli detected in one-tenth cubic centimeter of the water from any swimming pool, and only in one instance, a sample from the Aborn Street Baths, was the organism found in a volume as small as one cubic centimeter. As the water with which this pool was filled gave frequent positive tests for B. coli in one cubic centimeter at this time, the origin of the organisms found in this sample is at least open to question. The results of bacterial analyses of the water from these various pools are shown in Table 3.

In connection with our bathing load figures, it was very desirable that we should have some definite information as to

TABLE 3.

RESULTS OF BACTERIAL ANALYSES OF RHODE ISLAND SWIMMING POOLS.

	AVERAGE BACTERIA PER CC.			OCCURRENCE OF B. COLI IN ANY SAMPLE.		
	20° C	37° C				
		Total.	Red.	0.1 cc.	1.0 cc.	10. cc.
Brown University	10	3	1			0
Providence Y. M. C. A.	17 000	2	0	0	0	..
Pawtucket Y. W. C. A.	150	0	0	0	0	0
Pawtucket Y. M. C. A.	32	6	1	0	0	..
Newport Y. M. C. A.	17 000	2	1	0	0	0
Newport Army and Navy Y. M. C. A.	28 000	65	3	0	0	..
Woonsocket Y. M. C. A.	5 500	4	1	0	0	0
Moses Brown School	380	1	1	0	0	0
Pawtucket Boys' Club	1 300	10	0	0	0	..
Aborn Street Baths	13 500	30	17	0	..	..
Lundin Baths	140	23	11	0	0	0

the amount of pollution introduced into the water by each bather. As the pool at the Pawtucket Boys' Club is refilled each Monday and the pool at the Pawtucket Y. M. C. A. is cleaned and disinfected on the same day, and as neither pool receives any further treatment during the remainder of the week, it seems probable that data on mass pollution might be obtained by an extensive study of these pools. The results of analyses of series of daily samples from these pools, however, failed entirely to yield the desired information. In both pools there was an increase in the bacterial content of the water during the first and second days of use, but no proportionate increase was apparent on succeeding days, and at the end of the week the numbers of bacteria were not unduly large. Furthermore, no regular change in the chemical quality of the water could be detected by the ordinary analytical methods.

Even after long use the water in these pools which were provided with repurification systems was, generally speaking, of lower color and better appearance and sometimes of better chemical quality than the city water which was used in filling them. A certain increase in the soluble constituents was usually to be observed as these pools were continued in use. In one instance an increase of 50 parts per million in hardness was noted during an interval of 129 days, and in another instance the chlorine increased about 20 parts in 53 days. Increases in free ammonia and in nitrates amounting to about 2.0 parts in 56 days and 131 days were also noted, respectively. In the majority of cases, however, the total accumulated amounts of these soluble ingredients were no greater than the amounts found at times in certain of our public water supplies.

DISCUSSION.

The Brookline Swimming Pool.

Mr. L. K. Nason.* The Brookline swimming pool is the oldest municipal swimming pool in this country. It was opened twenty-one years ago January 1. Pools at that time were confined mostly to local well-to-do clubs and some few colleges. So the architect who planned the Brookline pool did not have the data which has been available for the last eighteen years, but had to obtain his information from England and Germany. That he did a good job is evidenced by the fact that the pool has stood for twenty-one years, and has never leaked. We have, within the past year, made a considerable number of changes there, but not in the pool construction itself. We have added dressing rooms around the sides of the pool and put in a new gutter. The type of pool that the architect built at that time is a type we are now building in some cases, but most of them now are entirely of concrete with an inner layer of mosaic or tile. The Brookline pool has a concrete outer shell lined with glazed bricks. Another type has a thin shell of about 6 or 8 ins., — waterproofed with tarred paper, — then a lining of common bricks, then a lining of about an inch of cement, and finally a mosaic lining placed over that. Some of the early pools were built with a patent water-tight concrete, but they did not work. The only patent concrete waterproofing is a good inspector on the job.

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* Director of the Brookline Municipal Swimming Pool.

The Brookline pool, as I said, has an outside shell with a brick lining. It is in a T-shaped building, — the office being in the center of the headhouse. At the time it was built, on the right of the office was a small instruction pool, 15 ft. by 10 ft., and on the left-hand side of the door as you entered was a common shower bath in which the people of the town had a perfect right to take a shower, towels and soap being supplied free. I think Brookline and Chicago are the only municipalities which furnish absolutely free baths. We have now on each side of the pool 31 dressing rooms, and on the right upstairs we have 18 private shower baths. The pool is placed in the rear of the building. It is 26 by 80 ft., and is 4 feet deep at its shallow end and 7½ ft. at the deep end. Whether or not steps are needed depends a good deal on what the pool is to be used for. I believe where women and girls are to use the pool, one flight of steps should be placed at each end. Where only men and boys use the pool the steps can be omitted. The pool has an overflow gutter around the four sides of the tank. The water enters at one end and goes out at the other. The tank holds 75 000 gals. of water, which is obtained from the town supply, and is heated by an injection of steam as it passes in through a pipe. The water is filtered by three Norwood filters. There were two reasons for choosing the Norwood filter. One was that it has three units independent of each other. If one breaks down, you still have the other two. The main reason is simply that when you have cleaned out the tank with the Norwood filter and have used the water that is in the pool, it thereby gives you the opportunity of replacing the water in the pool with fresh water, so you can keep your pool water much livelier and add fresh water much oftener than if you use a one-unit system, where you have to use fresh or city water to clean your filters. The pool as it stands cost some $65 000; $50 000 when it was first built, and $15 000 for renovations. There has been an attendance of over 1 662 000 since operation started. We have a lot of swimming events at Brookline, and at one end of the pool we have an opportunity to put up bleachers on which we can seat 600. There is now an 8-in. walk all the way around it, and there is a coping around the edge 14 ins. wide and 6 ins. above the floor, so that no water, after it splashes, can go back.

The matter of operation has three distinct features, depending entirely upon the size, the type of people who are to use the pool, and where it is located. The size of a pool makes it easy or extremely difficult for those who use it to keep it clean. It is fairly easy for a college or some well-to-do club to keep its pool clean, because the type of people who use it have some idea of personal hygiene, and when a notice is put up to remove clothing and take a shower bath using soap, — they will obey the rules; but where a pool is to be used by a municipality where they have from 400 to 600 youngsters a day, and people from the section of the town where they do not believe in hygiene, — it is another problem to enforce the regulations. So a constant supervision of the pool is necessary if you are to obtain results which will be satisfactory. We will not find that in a pool which is catering to the boys or people of the slums, it will be possible to keep the bacteria down to such a low figure as in that of a well-to-do club. In our pool at Brookline we have on some days from 400 to 500 youngsters, the next morning we will have 100 to 150 women from the best section of the town. Our problem is not only to keep the pool in shape for the youngsters, but also for the esthetic women who come from some of our well-to-do homes, and who feel that the slightest bit of dirt that can be found is a subject for complaint. Efficient supervision, to my mind, is the greatest factor in keeping a pool sanitary. You may have all the appliances you can buy, — you may make a study of how best to disinfect the pool, how to use the filters, how to keep the water at a certain temperature, — and yet, if you have no person on your staff who is very much interested in the swimming pool, you will find it will degenerate at least thirty per cent. and the results you reach will be far short of what you expected. We keep the water at a temperature of from 75 to 78 degrees Fahr. The temperature of the room has to go up naturally with the temperature of the water, so the temperature of the room is 70 to 80 degrees at Brookline.

The department owns every suit and every towel, and no outside ones are allowed. Shoes and stockings are not allowed, but we insist that women shall wear caps. A cleansing shower bath, with soap, is required of every one before entering the pool. Concerning our particular pool, it is used by an average of 200 to 300 a day, and last August, on a very hot day, over 830 people used it. So it is some little problem to keep the pool sanitary for the next morning, when the women come. By the constant use of disinfectant and by constant vigilance, we have been able so far to keep the bacteria very low. That is something I do not have to bother about much, because our town board of health maintains a rigid inspection, and if it finds that anything is wrong it is reported to me at once. I recall that when we changed our pool we had a foot of water less for two days. I experimented to see if we had to add more disinfectant, and the inspector of the board of health reported to me that the number of bacteria was just a little higher than it ought to be. I was very much interested in the figures thrown on the screen showing the effect of adding disinfectant. At Brookline we have 75 000 gals. of water, and we add 2 lbs. of chloride of lime each night. It is done by the old-fashioned method of putting it in a bag, which our janitor drags over the surface. I have looked into the matter of the ultra-violet ray and chlorine tanks, and I am perfectly satisfied, as long as our board of health does not object, to use our own system, because our janitor has orders to use only 2 lbs. of chloride of lime each night, and as that is all he is given, I know it is used. The average man in a janitor's position does not realize the importance of a matter of this sort, and some night he might forget; so each week our man is apportioned his 12 lbs. of chloride of lime, and each day that is checked up to see that 2 lbs. have been used. We use 2 lbs. of alum per day. At Brookline, when the pool was first built, it was emptied every two weeks. Then, as it was impossible to keep the bacteria below the danger point, it was emptied every week, and finally each night. That was done for five or six years, at a cost of about $4 200. To-day we empty it every two weeks. When we emptied it each night we could not see the bottom of the pool. It takes now three days to clear out our pool so that you can see the bottom. Our filters have a capacity of 75 000 gals. every ten hours, and that is the capacity of our pool. Our filters are never shut down. We continually add fresh water.

We have a small water tank into which steam is played, and from which a pipe leads directly to the alum accumulator tank. That enters the tank and passes from the tank to the water going into the filters, so we have a one-inch pipe flowing into our pool all the time.

The overflow gutter is a good thing when used as it should be. But to be of service the water must be continually kept at the edge of the gutter. The thought I have of the gutter is that when a man dives with a splash, the water should go into the gutter.

Regarding the adding of fresh water, as I said, the cleaning of our filters is done every morning. It takes about a foot of water out of our pool to clean our filters as they should be cleaned. So you see our pool is filled actually oftener than every two weeks. On Tuesday and Thursday afternoons, when we have the little fellows in, our pool is dropped down eighteen inches below the top. Then it is brought up to the top, so we use a foot and a half of water on these two days.

One of the greatest troubles we had with the old pool was that so many people got cold after using it, as they had to dress in the same atmosphere that they took a swim in. That is one of the reasons why we took our dressing rooms from the side of the pool. They are now kept at from 65 to 70 degrees, so that after a person leaves the hot room he does not have to dress in such a hot atmosphere.

Fig. 19 shows the hair-drying room, and Fig. 20 gives a general view of the pool. A suction motor takes hot air from the closed radiator below, and passes it through 2-in. pipes. That is something I have worked out myself, and it is very satisfactory. Where you have to handle women and girls in the winter time, some arrangement must be made to dry their hair.

A water suction system, furnished by the Sanitary Dust Removing Company, has been installed to remove the dirt which is bound to accumulate on the bottom of the pool. This is done every morning before the pool is used at all. Then every two weeks the pool is emptied and washed with acid. The brush sucks up the dirt from the bottom. This is done at the same time that the pump sucks the water up. The bottom is

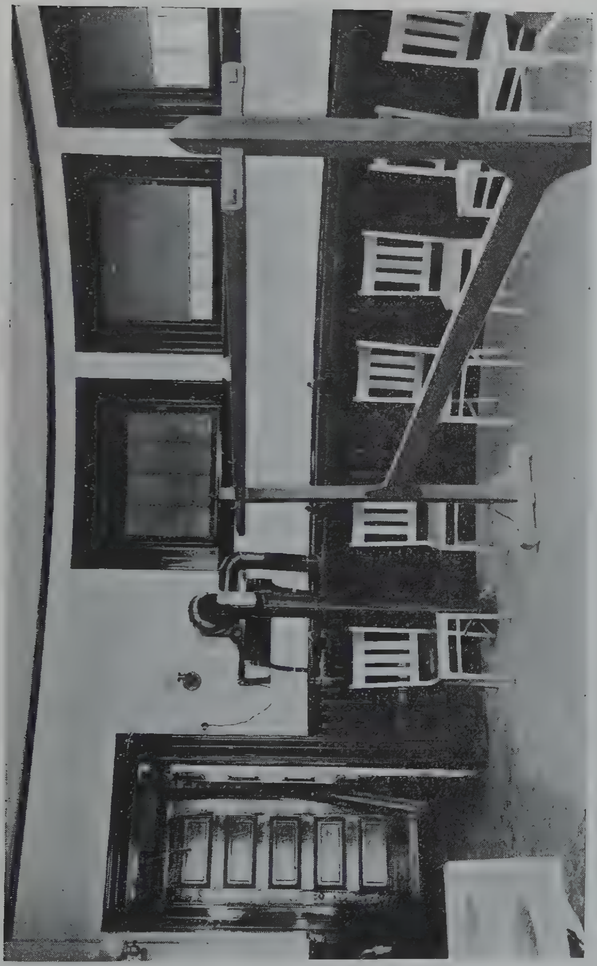

Fig. 19. Brookline Swimming Pool. Hair Drying Room.

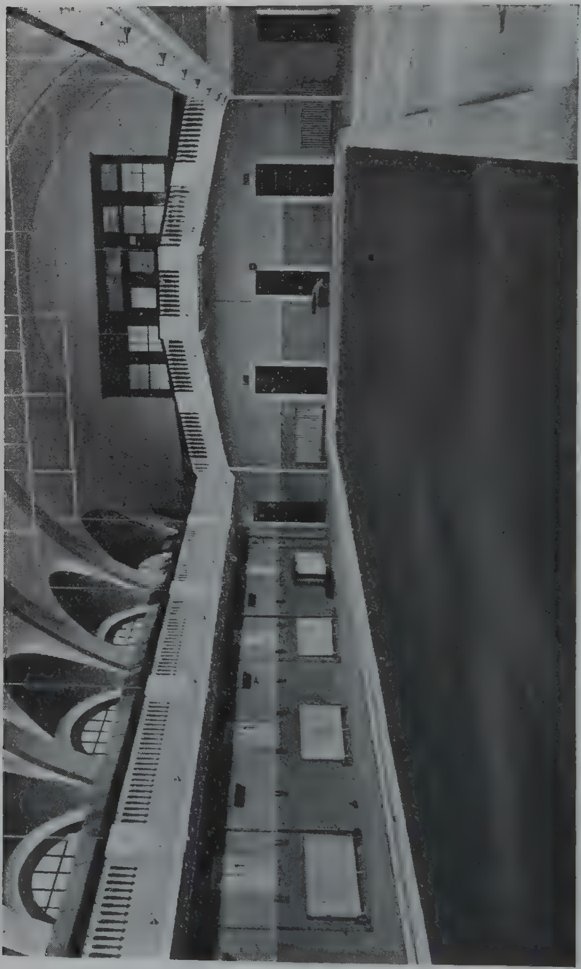

Fig. 20. — Brookline Swimming Pool.

concrete, with mosaic tile over it. You will find some pools now with cement bottoms only, which is dangerous from the fact that you cannot see the bottom. That is the reason we put in the filter at Brookline, because of the danger of somebody drowning. Where we handle from 600 to 800 a day, it means that we must be constantly on the alert to see that youngsters do not get drowned. Some people have said: "How can you handle 800 people in one day in a swimming pool 26 ft. by 80 ft.?" We do it by having half-hour periods. On each side of the entrance to the building there are two dressing rooms. It is arranged so that while the boys or parents are undressing or dressing on one side, those from the other side are in the pool. We run half-hour periods. At ten minutes of the hour we let in one side. On the hour the other side comes out. We allow ten minutes for the boys to undress and get ready to enter the pool. We have a rigid law there in regard to boys especially and small girls, — that they must present themselves to an attendant who must pass them before they can enter the pool. For the women and men we have a period of forty minutes, which is the longest allowed. I feel that that is long enough for anybody. There have been since the pool was opened, twenty-one years ago, 1 668 000 people in attendance although not all have used the pool, because a large number of people use our bathhouse and take shower baths. I will give you last year's figures; so that you can perhaps see what proportion use our pool. The number using the swimming pool last year was 65 073. The number taking shower baths and not using the pool was 17 797, —making a total attendance of 83 879. The number of residents who used the pool was 61 000 and the number of non-residents 4 073. The number of three free lessons given to the people of Brookline was 5 365. Eighty-five per cent. of the children of Brookline know how to swim, and we are now taking them as young as eight years of age and giving them free lessons, because I feel that if a boy graduates from the grammar school without knowing how to swim, the chances are that he will not learn to swim. The number of lessons given last year was 1 975, and the receipts $4 272. It is pretty hard to give the expense of the department because our swimming pool and gymnasium department are run as one department, — but I figure it at about $16 000. For the gymnasium and bath department there was appropriated last year $29 200. The pool in Brookline is used by people from nearly every section of the town. We have to make different arrangements so that each section of the town can be reached. We have free periods and five-cent periods for the children, so that the poor boy has just as good an opportunity of using our pool as the rich boy. In the morning it is nothing unusual to see twelve automobiles before our swimming pool, and on Friday night, which is given over to men only, you will find 35 to 70 men in the pool. We use a small trunk for men and a one-piece loose suit for women, made from our own designs. As I said before, we are kept constantly on the alert to keep up the standard of the pool, and I have one man who sees that the rules of the department are carried out and that our rooms are kept clean. By giving him the power to carry on the department under my supervision, we obtain results. When we had the infantile paralysis scare the question came up of closing our pool. The board of health said, " No, that is one of the best assets we have," — so we kept it open. During the twenty-one years it has been open there has never been any epidemic of any kind. It is a constant problem to keep it clean; yet when one is interested in it, although he may not be able to keep it perfectly clean, he can keep it in shape where it will not be dangerous to the health of people.

Mr. Scaife.* — We are building a very large pool, — a pool that will hold 130 000 gals. of water. At Hartford, Conn., where I have been for the last five or six years, we have been using the liquid gas with apparatus made by the Wallace and Tiernan Company of New York, that dispenses the chlorine automatically. Our circulating pumps were circulating water at the rate of 100 gals. a minute. That meant that we needed a drop of gas every sixty seconds. We circulated the full contents of the pool every twenty-four hours, and after six months' use, with an average of 300 to 400 a day using the pool, specimens of water taken at six o'clock and one at night showed sixteen bacteria per cubic centimeter and absolutely no colon bacilli whatever. At the Waterbury pool, disinfected in the same manner, after six months' use by women and children, it showed absolutely no bacteria whatever from the tests. The beauty of the liquid gas is that it works automatically. You do not have to depend on the janitor to see that your chlorine is properly mixed, and from my experience I think it is a wonderful apparatus.

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* Director of Physical Education, Worcester, Mass., Y. M. C. A.

FREDERIC BONNET, Jr.* — In our work at the Worcester Boys' Club and at the Worcester Academy we began with a clean pool and fresh water. The accompanying diagram, Fig. 21, shows the results obtained at the Boys' Club. The pool was emptied on February 20, and you will note that the bacteria rose to about 175 000 in three days. They then diminished toward the end of the week. This is the accustomed curve for a pool using no disinfectants. On the 26th, 3 ozs. of copper sulphate were used every day with very little effect. About March 3, there was a decided drop to about 100, then there was a rise although we changed the application of the copper sulphate by treating on alternate days with 6 ozs. The increase was slight but tended to remain constant at about 1 000 bacteria per cubic centimeter. On March 12, common salt was added to the pool, so that the chlorine in the pool was 50 parts per million. This helped the copper sulphate in a very surprising way and practically gave us a sterile pool for some time. About April 7, however, certain types of bacteria began to develop and there was a rapid increase in the number of bacteria present. We therefore decided to use a small quantity of bleaching powder to get rid of these aftergrowths, and in this, as you see, we were quite successful. The curve for the Worcester Academy corresponds perfectly with that of the Boys' Club. You will note by this alternating treatment of copper sulphate and bleaching powder that the amount of bleaching powder which was necessary to give a sterile pool was very much less than would have been the case had the bleaching powder alone been used. During the past year Worcester Academy has been operating their pool along this line, and we have been making weekly bacterial counts, and the pool has been kept in practically a sterile con-

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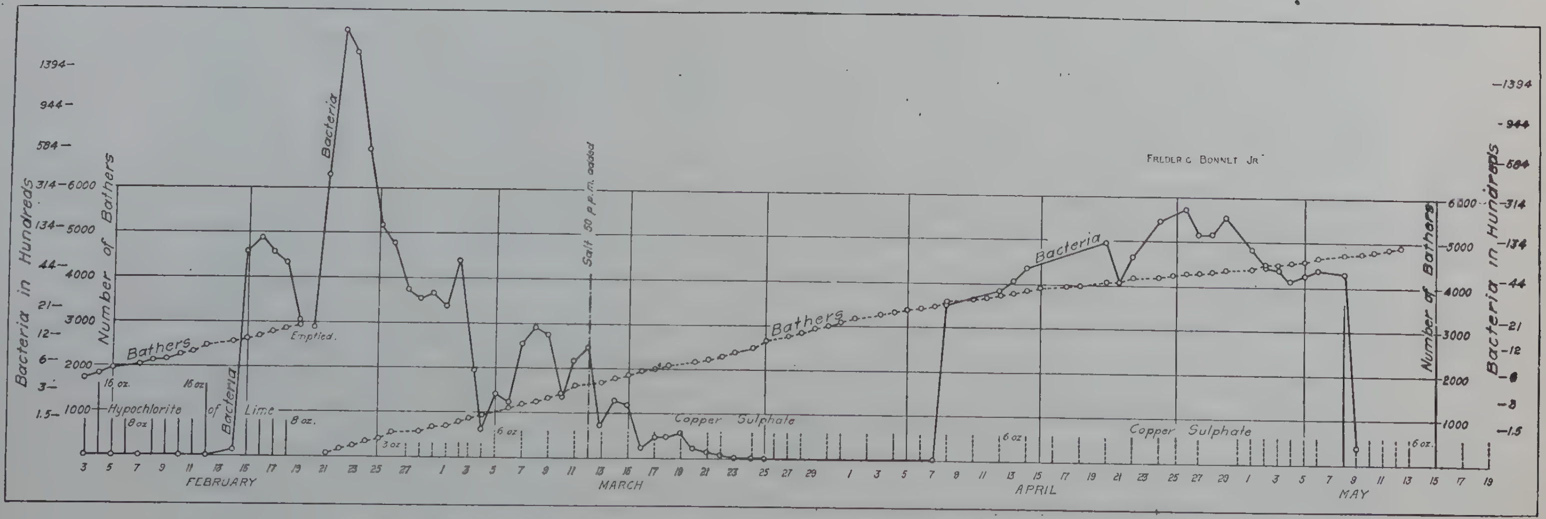

FIG. 21. ANALYSIS OF WATER FROM SWIMMING POOL AT WORCESTER BOYS' CLUB.

dition, occasionally the number of bacteria rising to 100, but for most of the time the plates are practically sterile. One interesting matter in connection with the Academy pool was the disintegration of the cement which held the small tile in place. Owing to the treatment of the water, this disintegration was laid to the chemicals which had been added to the water for sterilizing purposes. Further investigation showed that this disintegration would have proceeded even without the sterilizing chemicals. Further investigation shows that, in placing the tile, cement had been used without waterproofing. The most important point in the construction of the pool itself is to build it with waterproof materials, so that the water may not penetrate behind the tile, dissolve the bonding material and thus loosen the tile. If properly waterproofed this cannot take place. The pool was drained, all the cement was taken out as far as possible, with a wire brush, and the spaces replaced with waterproofing cement, and so far as I know has stood out very well since that.

ANSWERS TO QUESTIONS PROPOUNDED BY SWIMMING-POOL OPERATORS.

1. Why, when and how much alum should be used in treating the water in a swimming pool?
2. Why, when and how much alkali (soda ash?) should be used?

The amount of alum which should be used depends upon the quality of the water used. If the water is hard, due to bicarbonate of lime (alkalinity), a good precipitate will be formed with a small amount of alum. If the hardness is due to incrustants ($CaSO_4$) it becomes necessary to add soda ash to give a proper precipitate.

One grain per gallon of alum requires at least 7.7 parts per million of alkalinity to give a precipitate, or 1 grain per gallon of alum requires 8.2 parts per million of soda ash equivalent to 68 lbs. per million gallons.

3. How can growths be controlled?

Growths can be controlled by cleaning pool and scrubbing down walls with a solution of copper sulphate before refilling pool.

4. Why does heating the water for the pool cause growths in a pool lighted only by electricity (if such is true)?

(The growths are not specified — Growths develop in an ice-box drain which may be in the dark.)

5. How can dark-colored water be made clear?

Dark-colored water can be made clear by treatment with alum (very small amount) or alum and soda ash (see 1 and 2), settling, filtering, or both.

6. How often should the water in a pool be changed?

This depends upon the individual case — and I should say "when it needs it."

7. How can stains on the tile floors, coming from the bathers' feet and the use of rubber mats, be removed, or prevented?

Sometimes by scrubbing spots with a little muriatic acid.

8. What disinfectants give the best satisfaction in keeping the water free from pathogenic bacteria and at the same time being odorless, tasteless and harmless to the eyes and skin?

Ozone — see Public Health Reports, March 1, 1918.

9. What is the best method of keeping the bottom and sides of the pool clean?

Scrubbing with a weighted brush daily and giving a thorough scrub when pool is emptied.

LEVI H. GREENWOOD.* — The swimming pool in Gardner resembles the Brookline tank in its arrangement very much. We have also an outside pool about 100 yds. across in one direction and 80 in the other. It is located on the bank of a pond which is the town water supply. Across one end of this pond runs a railroad track dividing one part of it from the main town water supply. This little bay was gradually drying up and being filled up when we took it and decided to build a bath house there, — dig the pond out and make an outside swimming pool. We had to take out from four to six feet of muck all over the pond. We took it our with tip-carts, and to get the balance of it out, tried to blow it out with fire hose and finally took it out with wheelbarrows. Altogether we expended about ten thousand dollars on the cleaning out of that pond and calking the bottom with gravel, grading and sodding the banks. In the summertime we use that for bathers in the daytime and the inside one in the evening. We have been bothered very considerably ever since we started, by the growth of algæ. That is the only trouble we have had with it. The algæ grows and forms clusters or gobs, which float around in the water for about ten days in the early part of the summer. Then that disappears. We have tried everything we can think of to get rid of that condition, which is not at all dangerous, but decidedly unpleasant to bathers. Of course we use hypochlorite of lime for the bacteria and copper sulphate for that vegetable growth, and while that helps the matter somewhat it has not yet cured it. After ten days or so we get rid of it, — whether it dies a natural death or whether its death is mostly caused by copper sulphate I am not sure. Of course we shall never get a clear water in the outside pool such as we have in the inside pool, because it is not filtered water and the natural supply is not as clear as filtered water, but we would very much like information as to how we can overcome the growth. We are bothered by an algæ growth even in the inside pool, which will begin to discolor the tank in about five months despite the vacuum cleaner.

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* Trustee, Gardner, Mass., Municipal Swimming Pool.

MELVILLE C. WHIPPLE.* — The paper presented by Mr. Gage is a valuable contribution to the sanitation of swimming pools, both because of the information it includes and because of the new angles of approach to the problem which he has employed. It is to be hoped that he will be able to carry his work further, to the limits which are justified by the new methods of study. In the meantime it will be profitable for others to make appliction of some of the suggestions given in Mr. Gage's present paper.

During the past two years the swimming pool at the Cambridge Y. M. C. A. has been under the inspection of the Laboratory of Hygiene and Sanitation at Harvard University. Special studies have been carried on by research students, and regular inspections have been made from the laboratory. Through the courtesy of Mr. Waters, physical director, I have varied the system of sanitary control from time to time, with the result that the present procedure is more effective and more easily carried out than that formerly used.

Operation of Cambridge Y. M. C. A. Pool.

The natatorium at the Cambridge Y. M. C. A. is a modern one, well lighted and equipped with a pool 20 by 60 ft. holding 53 000 gals. A high curbing surrounds the pool and a trough at the water's edge carries off drainage from the curb and expectorated material from the bathers.

The source of the water is a driven well 400 ft. deep. The water is hard, colorless and clear, but contains ordinary forms of bacteria to the extent of several hundred per cubic centimeter. In series with the pool is a centrifugal pump, handling 50 gals. per minute, a pressure filter containing sand, and a heater. Circulation and filtration is maintained about eighteen hours each day. A vacuum cleaning apparatus is used to eject accumulated balls of hair and lint which collect at the bottom.

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* Instructor in Sanitary Chemistry, Harvard University.

Men use the pool without trunks or clothing after they have taken a shower bath. On one or two days a week during certain hours women are given the use of the pool. They wear suits provided by the institution. The heaviest contamination has been found to occur on these days. In warm weather the daily attendance of men reaches one hundred or more, in cold weather it is somewhat less than this.

Filtration and the Use of Alum.

Like most pressure filters the one installed was designed to make use of potash alum as a coagulant for the water. Mr. Gage has described the alum pot and the way in which a small stream of water is by-passed through it to dissolve the alum and carry it to the water entering the filter.

At the time studies were first undertaken, a weekly dose of potash alum of 30 lbs. per million gallons was being added to the alum pot. This was continued for a time while disinfection experiments were made, but the water in the pool was at all times slightly opalescent or cloudy. The bacterial efficiency of the filter was not very great, varying from 20 per cent. to 60 per cent. Experiments were then made *without* the use of alum and it was found that the appearance of the water was much improved, and the efficiency of the filter was not noticeably affected. On the basis of these experiments alum treatment was discontinued and none has been added for two years.

This procedure is obviously out of the question when surface waters are used as it is then desired to remove the color and clear the water, but it is practicable for well waters. When alum is used there is not time for coagulation before the water passes to the filter. It occurs later in the pool, and produces a noticeable turbidity.

The Use of Copper Sulphate.

Disinfection was formerly carried out at the Cambridge pool by means of chloride of lime, added in the proportion of 20 lbs. per million gallons on every other night. The results were fairly satisfactory measured by bacteriological standards, but there were occasional complaints of taste in the water and irritation of mucous linings. The latter were no doubt stimulated by the occasional odor of chlorine in the natatorium and by its taste in the water.

A long series of experiments were made with copper sulphate. Not only was it desired to restrain bacterial growth in the pool, but some method of controlling algæ growths was sought. Algæ chiefly diatoms, were frequently troublesome by growing on the white tile and forming unsightly brown patches. Copper sulphate proved a cure for this condition. Its use has also maintained a satisfactory bacterial content, the number of 37 degrees Cent. (organisms varying from 0 to 10, and the 20 degrees Cent.) organisms from 1 000 to 40 000 per cubic centimeter when the proper dose was applied. B. coli, the intestinal bacterium, is almost never found.

For over a year copper sulphate was added three nights each week in the proportion of 1.1 parts per million, or about 9 lbs. per million gallons. Recently the dose was increased to 0.9 parts per million, or 7.5 lbs. per million gallons, each night. This was found to still further reduce the number of bacteria growing at 20 degrees Cent. This small amount — about 0.4 lb. — is hung in a cloth bag over the outlet from the pool, and is dissolved while the water is being circulated.

At one time the copper sulphate was put into the alum pot of the filter. When it became necessary to replace the pot with a new one, the bacterial content of the pool increased rapidly. It was found that the cast-iron alum pot became choked with a brown mud, which was 75 per cent. metallic copper. Consequently the copper was not available for disinfection. This displacement of copper from solution by means of iron is a point to bear in mind when copper sulphate is used. It should not be put in iron receptacles to dissolve.

The water in the Cambridge pool has not been drawn off for about fifteen months, and during that time has been kept in a satsifactory condition, as evidenced by a large number of analyses. The tile is clean and the water clear and of satisfactory bacterial content. With surface waters it is possible that copper sulphate may not be an acceptable disinfecting agent, but with well waters it may be used and has the following advantages:

1. It does not deteriorate or lose strength in storage.
2. It is odorless and tasteless in the quantities used.
3. It is easily handled and weighed.
4. It prevents the growth of algæ in pools and on the tile.
5. It is precipitated finally by the alkalinity of the water and tends to accumulate on the sand of the filter where it exerts a further bactericidal effect.
6. It apparently exerts a selective action upon the forms of bacteria growing at a body temperature, 37 degrees.

Beneficial Effects of Flushing.

There is a considerable volume of water lost from a pool each day from splashing and evaporation. In a week this may amount to a depth of one foot. The restoration of this loss by means of fresh water is a great factor in maintaining proper hygienic conditions. It is advisable to add fresh water as often and in as large volumes as possible, but economic considerations will generally be found to govern this. At the Cambridge pool it was formerly the custom to add about 8 000 gals. each day, but during the past year this has been reduced to about 10 000 gals. each week, owing to a scarcity of well water. Nevertheless the condition of the pool has been quite satisfactory.

When water is added, the level should always be brought to the edge of the trough and allowed to overflow. Analyses have shown that the surface layers of a pool which has been allowed to stand quiet over night contain considerable floating material and a bacterial content much higher than the water at a depth of one foot. It is thus possible to " skim " off this dirtier water. If circulation with a pump is maintained over night the surface accumulations of dirt and bacteria will be less, but will still occur.

The points brought up in this discussion did not originate from work in connection with a large number of pools. In fact, they were suggested from the operation of only two pools, but they are presented here with the hope that they may prove valuable or suggestive to those operating pools under conditions comparable to those described.

Answers to Questions Propounded by Swimming-Pool Operators.

1. Why, when and how much alum should be used in treating the water in a swimming pool?

Alum should only be used in swimming pools when the water is subsequently filtered to remove the precipitated aluminum compound. Some waters do not require alum. These are the clear, colorless waters from underground sources. When coloring matter or turbidity are present in the water, alum will remove these as the contents of the pool are filtered over and over.

From 0.25 to 1.5 grains per gallon, or 36 to 215 lbs. per million gallons, of potash alum will be required to properly clear the water. The actual quantity used is based upon the capacity of the pool and is added to the alum chamber of the filters. There it dissolves slowly as the water circulates through the filters. The dose may be repeated weekly, or more often according to the rate of filtration and the appearance of the water.

2. Why, when and how much alkali (soda ash?) should be used?

Soda ash need never be added to a swimming pool unless alum has been added in such an amount as to neutralize the natural alkalinity. Artificial alkalinity is then supplied by the soda. Each grain per gallon of alum neutralizes 7.7 parts per million of natural alkalinity. If it is desired to supply alkalinity with soda ash, one part per million of alkalinity will be supplied by every 8.8 lbs. of soda added to each million gallons.

3. How can growths be controlled?

If by growths, algæ are meant, these are easily controlled by the addition of copper sulphate. This substance is an excellent algicide, and also a good germicide, if the water contains only a slight amount of color and turbidity. Chloride of lime is not efficacious and reliable for keeping down these growths. Pools regularly disinfected with chloride of lime have exhibited growths of algæ on the tile.

In the treatment of the Cambridge Y. M. C. A. pool 0.9 parts per million of copper sulphate is added each night, and this serves to prevent all growths of algæ and to disinfect the water in a satisfactory manner. About one part per million is the average dose used in the treatment of water-works reservoirs.

4. Why does heating the water for the pool cause growths in a pool lighted only by electricity (if such is true)?

Heating the water would only cause growths of algæ by virtue of raising the temperature of the whole pool to a point which might provide optimum conditions of growth. There is a critical temperature for all species below which they do not readily reproduce.

5. How can dark colored water be made clear?

Dark-colored water is usually made so by the presence of vegetable coloring matter. This can be removed by treating with alum and filtering as described under Question 1. It is not advisable to use deeply colored water if any other source is available, for the task of maintaining an efficiency of filtration which will produce water of a satisfactory appearance in the pool is seldom possible of accomplishment.

Filtration without the use of alum will remove only a small portion of coloring matter.

6. How often should the water in a pool be changed?

The expense of emptying and refilling the pool and the amount of inconvenience encountered by reason of not having the pool available for use during this process will determine the frequency of change. It goes without saying that as much fresh water as possible should be added. A continuous stream of clean water flowing through the pool is the ideal condition.

If the water is not disinfected it should not remain in the pool longer than one week with perhaps 50 to 75 bathers each day. Even then the dangers from contamination are greater than would be the case if disinfection was practiced and the water allowed to remain for two or three weeks. Disinfection should be practiced in all pools not subject to a continuous flow of good water.

If filtration and disinfection are both practiced, and the quality of the fresh water is good, then refilling may be postponed for many weeks or months, if a considerable volume of fresh water, say one eighth to one fifth the capacity of the pool, is added weekly. Nearly every pool is a law unto itself in the matter of bacterial contamination. Analysis alone will show the true conditions, which will vary with the " bathing load " and the character of the water used.

7. How can stains on the tile floors, coming from the bathers' feet and the use of rubber mats, be removed, or prevented?

Rubber mats are a source of annoyance from gradual disintegration and from the collection of dust on their rough surfaces. They require frequent scrubbing with plenty of water. Stains from them are best removed with a strong solution of soap powder, or with gasoline.

8. What disinfectants give the best satisfaction in keeping the water free from pathogenic bacteria and at the same time being odorless, tasteless and harmless to the eyes and skin?

Bleaching powder, chloride of lime, is an efficient disinfectant and totally harmless in the quantities required. A slight odor or taste is often apparent when it is used in waters containing no organic matter to absorb the slight excess necessary for disinfection. The use of copper sulphate has met with success in the treatment of such waters. (See discussion submitted by M. C. Whipple.)

Ozone and ultra-violet light have been used to a limited extent. Their installation is rather expensive, more complicated to operate and not suited to all waters.

9. What is the best method of keeping the bottom and sides of the pool clean?

The vacuum brush will keep the bottom and sides of the pool clean if used each day or two. It stirs up the dirt and sucks it out in a stream of water. Hydrochloric or oxalic acid may be used in dilute solution to remove stains from the tiling when the pool is emptied.

R. S. Weston.* — In the matter of bathing in ponds used as sources of water supply Dublin Pond, in the Monadnock region, may be mentioned. This is a beautiful sheet of water, about half a mile in diameter and perhaps 60 ft. deep. It is used as a source of water supply and a general place of recreation for the cottagers surrounding it, some of the cottages being of large size and containing a great many residents in summer. They use one end of this pond as a bathing beach. They take great pains — they have an association — to prevent any pollution of the lake, and at the time I visited it and made an inspection, — which was some four or five years ago, — there was only one possible source of pollution. Most of the intakes for water were in 20 ft. of water and about 100 ft. or more from shore. They have a very good laboratory there, run by a local physician and supported by the cottagers, which keeps control of the milk and water supply. They found that in depths of 20 ft. or more the water was practically free not only from sewerage bacteria but from all bacteria that would ferment, — i. e., in any way relating to intestinal bacteria. So when the question was asked us what they should do with their water supply, we felt that if they would place their intakes at a depth of 30 ft. they could still use that water for drinking purposes. Regarding the use of a pond for a swimming pool, I should want, in giving advice of that kind, to know my pond; but to use it as a source of ice supply — cutting the ice six months after it ceases to be used as a swimming pool — I think it would be entirely without objection. In the first place we have the element of time there. The bacteria decrease very rapidly — particularly disease bacteria — in water rich with flora. In water of that kind animalculæ grow, and these will feed on the bacteria and reduce the number very rapidly. In thirty days' time it is doubtful if any considerable number of disease germs remain according to experiments which have been conducted; and if the water is to be used for general recreation purposes and for bathing in summer and then allowed to rest during the fall, there ought to be no reason why it would not be all right in the winter.

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THE CONSTRUCTION AND SANITARY CONTROL OF SWIMMING POOLS IN MASSACHUSETTS.

FRANK A. MARSTON.* — In order that this discussion might be supplemented by a résumé of the practice in construction and operation of swimming pools in Massachusetts, blank forms were sent to a number of institutions operating pools. Replies have been received in regard to 34 pools, and the results are summarized in the following paragraphs and in Tables 4 and 5. The pools vary considerably in construction and methods of operation. The data are instructive, as indicating the present state of the art in this vicinity, and the replies received indicate that the majority of the operators are anxious to maintain sanitary pools and are willing to receive assistance in accomplishing that end. No attempt was made to collect data regarding the "plunges" or small pools, of which there are many.

CONSTRUCTION.

Shape. — The pools listed in Table 1 are rectangular in plan, varying in length from 28 ft. to 100 ft., twenty-two of them being 60 ft. or over in length; and varying in width from 18 ft. to 30 ft.

Depth. — The maximum depth is, in most of the pools, at least 7 ft., and the minimum depth at the shallow end is in the vicinity of 3 ft. 6 ins. Where a spring-board is used, the maximum depth is located from 10 to 15 ft. from the end at which the board is attached, in order to bring the deep water where it is needed for diving. The bottom slopes from either end to the deepest point, thus facilitatng the draining and cleaning of the pool.

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Location of Inlets and Outlet. — In the well-designed pools the inlets are distributed across the shallow end near the top, and the outlet, usually only one, is at the bottom in the deepest section.

Spit Troughs. — The general opinion expressed was that there should be a spit trough extending around the pool on all four sides. This trough should be designed to serve, also, as a handrail and an overflow and splash trough. It should not project out into the pool on account of the danger of the bathers striking it when jumping into the pool. It has been suggested that there should be provision for automatic, periodic flushing of this trough, to prevent the occasional washing back of the contents into the pool by a wave.

Walk Drainage. — The walk about the pool usually has a raised edge to prevent water dripping from the bathers or dirt from the feet from entering the pool. Some means of automatically flushing this surface into a drain or into the expectoration troughs has been suggested as a needed improvement. Objection to the raised edge on the walk has been made on account of the danger of bathers tripping over it.

Materials of Construction. — All of the pools are constructed of concrete with white tile lining on the sides, the bottoms being lined, for the majority, with white tile, marble or mosaic. It is essential that the pools be water-tight, and to this end special precautions should be taken in construction.

Location of Pool. — Too often it appears that a pool is located in the basement space remaining after all other purposes have been served. Many of the operators mentioned the desirability of locating the pool so that daylight is available during the day, for lighting the room, and there is ample ventilation to the outside air.

Some operators expressed the opinion that direct sunlight

TABLE 4. — DATA RELATING TO SWIMMING POOLS IN MASSACHUSETTS.

LOCATION.	DIMENSIONS OF POOL IN FT.				Approximate Capacity of Pool in Gallons.	Source of Water Supply.	Frequency of Emptying per year.	Hours per day Circulation Pump Operated.	Average number of Bathers per Week.	Capacity of Pool in Gallons per User per Week.
	Length.	Width.	Max. Depth.	Min. Depth.						
Amherst College, Amherst.......	75	22	7.75	4.75	75 000	Munic.	2–3	5–7	800	94
Beverly Y. M. C. A..............	40	20	8	3	40 000	Munic.	1	12	450–500	84
Boston Athletic Association.....	40	30	7	..	45 000	Munic.	13	24	100	450
City of Boston—Curtis Hall.....	75	25	7	3.5	75 000	Munic.	12	24	S–2 000	37
City of Boston—Columbia Road[3].	40	30	4	4	20 000	Munic.	104	..	200–1 000	33
City of Boston—Cabot Street[3]...	75	25	7	3.5	75 000	Munic.	104	..	300–700	150
Boston Y. M. C. A.............	75	25	7.5	3.5	78 000	Wells	13[6]	18	860	91
Brookline Municipal............	80	26	7.5	3.83	75 000	Munic.	26	24	1 150	65
Cambridge Y. M. C. A...........	60	20	7.5	3.5	53 000	Well	1 per 14 mo.	18	1 200–1 500	39
Dean Academy, Franklin........	50	20	7.5	3.5	43 700	Munic.	2	5	100	437
Framingham Civic League......	75	25	7.5	3	89 000[4] 68 000	Munic.	....	..	..[5]	..
Gardner, Greenwood Memorial...	75	30	7.5	3	90 000	Munic.	2.4	8	S–1 140	79
Gloucester, Y. M. C. A..........	28	20	7	4.5	24 000	Munic.	12	5	100–250	137
Haverhill Y. M. C. A...........	38	19	7	4	29 700	Munic.	6	9[1]	500	59
Lawrence Y. M. C. A...........	60	20	7	3	46 000	Munic.	1	4 to 8	500	92
Lowell Y. M. C. A..............	60	22	9	4	65 000	Canal	13	10	...	..
Lynn Y. M. C. A...............	40	20	8	4	33 000	Well	4	10	450	73
Malden Y. M. C. A.............	60	20	7.5	3.5	55 000	Munic.	4	10	400–500	122
Melrose Y. M. C. A............	40	20	7	3	33 000	Munic.	1	20[2]	300	110
New Bedford Y. M. C. A........	40	20	7	4	35 000	Munic.	2–2.4	17	250	140
Newton Y. M. C. A.............	60	21	6.5	3	50 000	Munic.	0.33	12	500–600	91
Norwood Civic Association......	60	20	8.5	4	60 000	Munic.	....	14	350	171
Quincy Y. M. C. A.............	32	18	6	4	21 550	Munic.	4 or more	6	50	430

Phillips Academy, Andover......	75	30	8.5	4	88 000	Munic.	3	10	600	147
Phillips Academy, Exeter, N. H..	75	26	8.87	3.87	97 000	Wells	....	..	..[5]	..
Radcliffe College, Cambridge....	60	20	7	4.5	50 000	Munic.	91	..	164	305
Somerville Y. M. C. A..........	35.67	19.17	6	3.5	32 560	Munic.	2	5–6	300–400	93
Springfield Y. M. C. A..........	75	25	7	3.5	75 000	Munic.	17	24	900	83
Taunton Y. M. C. A.............	40	25	6.5	3	26 200	Munic.	....	8+	260	105
Waltham Fellowship House.....	66	25	6.25	3.5	55 000	Munic.	26–52	3+	S600–800	79
Worcester Academy............	75	30	10	5	120 000	Munic.	1	4	300	400
Worcester Boys' Club..........	60	20	7.5	3	45 000	Munic.	104	12–15	500	90
Worcester Y. M. C. A...........	100	25	8	4	130 000	Sp. water	2	14	..[5]	..
Y. M. C. A. College, Springfield..	60	24	8	4	75 000	Well	1–2	10	1 500	50

S — Summer. [1] Every two days. [2] Per week. [3] Operated seven days per week. [4] For games and contests, larger figure can be made available. [5] Pool not placed in use up to time of reporting. [6] About 4 ft. of water added per day.

TABLE 5. — DATA RELATING TO OPERATION OF SWIMMING POOLS.

LOCATION.	Rate of Circulation Pump. (Gals. per Min.)	COAGULANT.		ALKALI.		DISINFECTANT.		Temperature of Water. Degrees F.
		Kind.	Pounds per Week. (6 days.)	Kind.	Pounds per Week. (6 days.)	Kind.	Pounds per Week. (6 days.)	
Amherst College, Amherst	150	Alum	2.5	Soda ash	2.5[2]	Chloride of lime	$1\frac{7}{8}$	75
Beverly Y. M. C. A.	....	Alum	....	....	....	Copper sulphate	$1\frac{1}{8}$	76–78
Boston Athletic Association	....	....	....	....	....	Chloride of lime	1	70
City of Boston—Curtis Hall	....	Alum	4	Soda ash	4	None	....	70–74
City of Boston—Columbia Road[3]	None	None	....	None	....	Chloride of lime	3	70–74
City of Boston—Cabot Street[3]	None	None	....	None	....	Chloride of lime	3	70–74
Boston Y. M. C. A.	....	Alum	....	....	....	Copper sulphate	0.3	72
Brookline Municpial	125	Alum	2	....	....	Chloride of lime	12	75–78
Cambridge Y. M. C. A.	50	None	....	None	....	Copper sulphate	4.8	70
Dean Academy, Franklin	....	....	....	Soda ash	....	Chloride of lime	....	65
Framingham Civic League	....	Alum	....	Soda ash	....	Chloride of lime	....	....
Gardner, Greenwood Memorial	150	Alum	0.75	....	....	Chloride of lime Copper sulphate	2.25 0.3	74–75
Gloucester Y. M. C. A.	....	Alum	3	Soda ash	7	Chloride of lime	3	71
Haverhill Y. M. C. A.	....	Alum	3+	Soda ash	3+	Chloride of lime	0.25	67–72
Lawrence Y. M. C. A.	65	Alum	....	Soda ash	....	Chloride of lime	3	....
Lowell Y. M. C. A.	100	....	....	Soda ash	5	Chloride of lime	0.25+	....
Lynn Y. M. C. A.	....	Alum	0.25	Soda ash	0.25	None	....	65–70
Malden Y. M. C. A.	83	Alum	10	Soda ash	1.25	Chloride of lime	5	72
Melrose Y. M. C. A.	....	Alum	....	....	....	Chloride of lime	1	65
New Bedford Y. M. C. A.	30	Alum	3	Soda ash	0.25	None	....	76
Newton Y. M. C. A.	....	Alum	1	....	....	Chloride of lime	3	74
Norwood Civic Association	....	Alum	3	Soda ash	1.5	Chloride of lime Copper sulphate	0.25	73–74

Quincy Y. M. C. A.	. . . .	Alum	. . . .	None	. .	Chloride of lime	0.75	70
Phillips Academy, Andover	110	Alum	7.5	Soda ash	10	Chloride of lime	6	70
Phillips Academy, Exeter, N. H.	. . . .	. . . .	. . . .	. . . .	. . .	Chloride of lime	. . . .	. . . .
Radcliffe College, Cambridge	83	None	. . . .	Soda ash	5	Chloride of lime	3	72
Somerville Y. M. C. A.	. . . .	Alum	0.25 to 0.5	Soda ash	1	Chloride of lime	0.19	70
Springfield Y. M. C. A.	100	Alum	13	. . . .	.	Ultra violet rays	. . . .	74
Taunton Y. M. C. A.	. . . .	Alum	. . . .	. . . .	. . .	Chloride of lime	0.25	70–72
Waltham Fellowship House	. . . .	Alum	. . . .	. . . .	. . .	Chloride of lime	2.25 to 3	66–74
Worcester Academy	. . . .	Alum	1	.	. . .	Chloride of lime Copper sulphate	3 3	70–76
Worcester Boys' Club	100	Alum	4	. . .		Chloride of lime	3.5	74
Worcester Y. M. C. A.	150	Alum	. . . .	Soda ash	. .	Liquid chlorine	. . . .	68–75
Y. M. C. A. College, Springfield	130	Alum	6	Soda ash	. . .	Copper sulphate Chloride of lime	3 . . .	76–80

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[1] One-quarter lb. per 1 000 gals. 3 times per week.

[2] When necessary.

[3] Operated 7 days per week.

was of advantage in keeping the water in good condition, but others found direct sunlight caused increased growths of algæ, and consequently was a source of further trouble. This latter would be especially true where ground water is used as a supply.

At all times the pool and room should be well lighted, thus increasing the attractiveness of the pool and making it all the more necessary to maintain sanitary conditions. Electric lights can be used at night, with good effect.

Operation.

Source of Water Supply. — It is interesting to note that five out of the thirty-four pools obtain their water from driven wells, and one uses spring water obtained on the property. All but one of the others use the municipal supply. The water for the Boston Y. M. C. A. pool is taken from two artesian wells over 400 ft. deep, and is salt.

Refilling Pool. — The period between times of emptying the pools and refilling completely, varies greatly. In nearly all of the pools a certain amount of fresh water is added daily, or every few days, to replace that lost by splashing or overflow, or washing filters, or drawing out sediment. In this manner the water may be said to be replaced once in three months, perhaps. Many of the large and well-operated pools are emptied but once in from five to twelve months, or even longer. The Cambridge Y. M. C. A. pool has not been emptied for about fourteen months, but the water is maintained in satisfactory condition by scientific treatment, as is indicated in the discussion by Mr. M. C. Whipple. The period during which satisfactory conditions can be maintained may depend to a large degree upon the extent to which algæ grows, although trouble from this source can be materially reduced by dosing with copper sulphate and by using a vacuum cleaner or suction brush.

By refilling only at infrequent intervals and provided, of course, that the quality of the water is maintained by treatment, substantial savings in water and heat are made, the color of the water is kept at a satisfactory point, and a uniformly low bacterial content can be assured. The water, supplied in the Metropolitan District, has sufficient color to be dark and unattractive

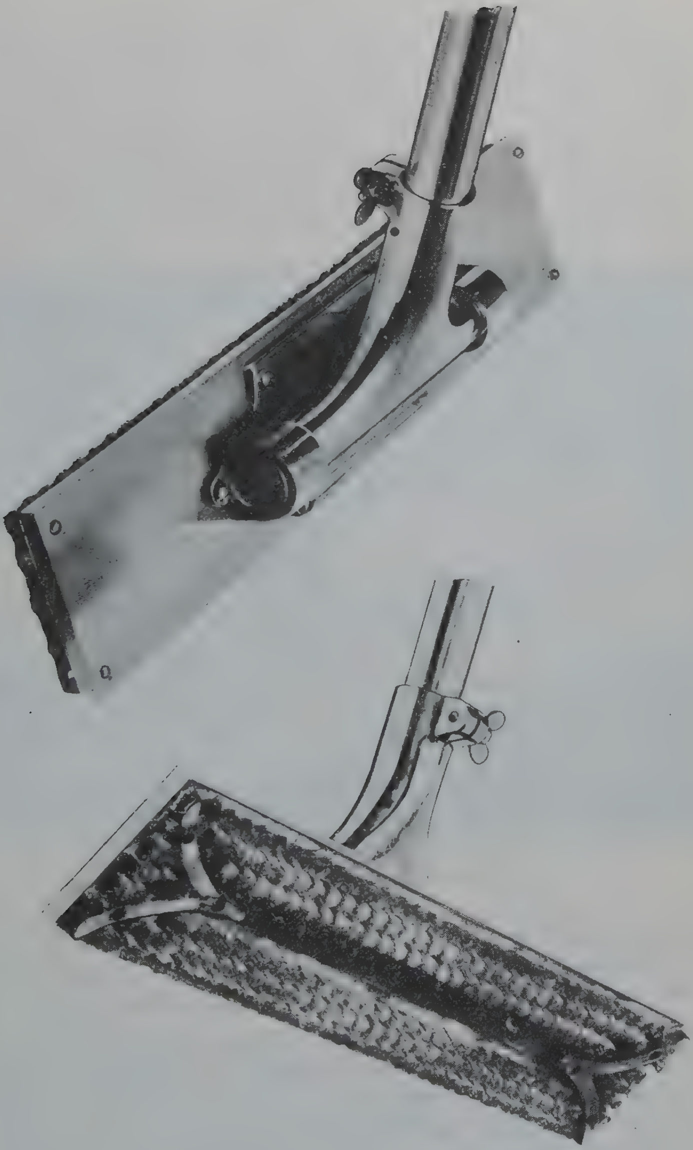

FIG. 22. SUCTION BRUSH.

when collected in a large white pool, although it is entirely satisfactory for a drinking water. After a few days in the pool, however, with proper treatment, the color can be reduced to a satisfactory degree, but where the pool is emptied every few days the color is liable to be uninviting the most of the time.

Removing Sediment. — The best method reported for removing sediment from the bottom of the pool is by means of a

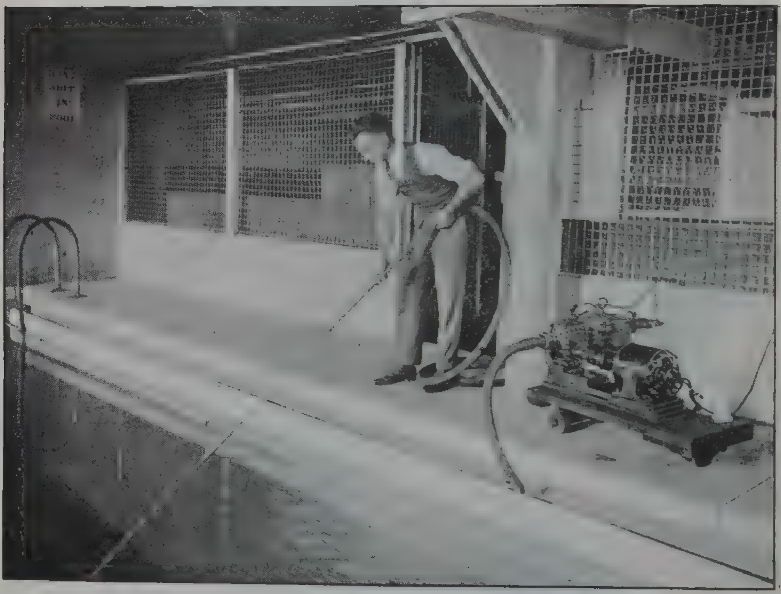

Fig. 23. Cleaning Quincy Y. M. C. A. Natatorium.

long-handled suction brush, somewhat similar to brushes used with vacuum cleaners. A brush of this type is shown in Fig. 22, the cut for which was loaned by the Sanitary Dust Removing Company, of Boston. The brush has short, stout bristles and is operated by a hollow handle through which water is drawn (when immersed) by a suction pump either stationary or portable. It is reported that centrifugal pumps have not given satisfaction for this service. Fig. 23 shows a brush of the above type, in use at the Quincy Y. M. C. A. It is connected to a little portable pumping outfit made up of a Kinney bronze rotary pump, size SD373, driven by a direct-connected 1½ horsepower Century motor, furnished by The Kinney Manufacturing Company of Boston. The pump discharge is through a flexible hose into the spit trough. The suction pipe is provided with a strainer and may have a check valve near the brush to maintain the priming of the pump while going from one side of the pool to the other. In general, the pump should have a capacity of about 50 gals. per minute when operating against a 10-ft. head (largely suction lift). The water may be discharged into the filters or wasted into the sewer. The latter method is generally used.

Filters. — All of the pools (excepting the Columbia Road and Cabot Street pools of the city of Boston) are equipped with mechanical filters for purifying the water. The majority are of the pressure or enclosed type. In either case, whether of the gravity or open type or the pressure or enclosed type, the sand is washed by pumping water through the filter in the reverse direction into the drain or sewer, to carry off the dirt accumulated in the sand. It appears evident that the water must be changed continuously or else circulated through a filter, in order to maintain an acceptable standard of purity. The former method is usually too expensive to be adopted. The circulation pumps should be operated at such a rate and for a sufficient period, especially during the hours of use, so that the entire contents of the pool may be filtered at least once a day. Needless to say, the filters should be of ample capacity to handle this rate of filtration.

In general, alum (aluminum sulphate) is used as a coagulant, to assist the filters, being applied either directly to the water in the pool, or by a feed device to the water in the pipe line entering the filters.

Alum requires a certain amount of alkalinity in the water for its proper action. The continual use of the same water by filtration, even though a small amount of fresh water be added daily, reduces the natural alkalinity to such an extent that with soft waters, additions must be made to the alkalinity from time to time, in order to prevent undecomposed alum from causing complaints. Seventeen of the pools reported the use of soda ash to maintain the alkalinity of the water.

The quantities of alum reported are listed in Table 2. In the case of the Y. M. C. A. College at Springfield, the pump operates at a rate of 130 gals. per minute for approximately ten hours per day, thus filtering about 78 000 gals. (the pool has a capacity of 75 000 gals.) Using 1 lb. of alum per day is equivalent to 12.8 lbs. per million gallons of water filtered, or about 0.09 grain per gallon, or 1.54 parts per million.

Disinfectants. — By far the most common disinfectant used is chloride of lime. Out of 34 pools reporting, 26 use this chemical, 4 of these pools using copper sulphate also, 3 others use copper sulphate only; 1 reported using ultra-violet rays (Springfield Y. M. C. A.); 1 uses liquid chlorine (Worcester Y. M. C. A.) and 3 use none of these agents, depending on filtration and the use of alum and soda ash.

The replies indicate that copper sulphate is recognized as of particular value in reducing growths of algæ, and by some is preferred for general use in the pool as a germicide.

Chloride of lime when fresh and properly handled has proven of great value. It deteriorates upon exposure to the air, and for that reason its use may lead to a false sense of security unless regular bacterial analyses of the water are made.

A common method adopted for applying the chloride of lime is to scatter the dry powder over the surface of the water. This is objectionable for the following reasons: The dry powder is objectionable to the caretaker who handles it in this manner; the odor permeates the room in an unpleasant way; fine particles float on the surface causing unsightly patches, or the larger particles sink to the bottom increasing the deposit of sediment; and the value of the chemical as a sterilizing agent may be reduced by the decomposing action of the air.

Professor Bonnet has suggested the use of a solution of 1 lb. of chloride of lime to 5 gals. of water. This mixture should be stirred for a few minutes, then allowed to settle, thereby getting rid of the insoluble portion. The solution can be distributed over the surface of the water in the pool by means of an ordinary watering-can with a long spout. Professor Bonnet further suggests the application of chloride of lime in a similar manner to the method frequently adopted in using copper sulphate. That is, to use a salt or cheese-cloth bag in which the powdered chemical is placed, the bag being fastened to a pole or weighted and attached to lines, thus permitting it to be drawn back and forth through the water all about the pool. In this way the objections previously raised may be overcome.

Where special apparatus is provided, as is preferable, for applying the disinfectant to the water as it leaves the filters, the above methods are unnecessary.

In recent years, apparatus has been developed for applying liquid chlorine to water, and is now extensively used for the disinfection of public water supplies. In the case of swimming pools, the first cost of the liquid chlorine apparatus is a large item. For general use, however, by unskilled operators, or where scientific supervision is lacking, chloride of lime is probably safer and more satisfactory. The use of the ultra-violet rays prevents the objection made by some to the use of any kind of chemical treatment. For such use it has been claimed, in some instances, to be more economical to operate than the older method of using chloride of lime.

Temperature of Water. — The temperature at which the water is maintained varies from 65 degrees to 78 degrees Fahr., the average being about 72 degrees. As a rule, the room is kept several degrees warmer than the water.

Methods of Heating Water. — Three methods of heating the water as it circulates from the pool and through the filters, are in general use. A steam-jacketed water tank or steam jacket around the supply pipe is the most common method, using either live or exhaust steam. A second method is to use a feed water heater such as are used in power plants for heating boiler feed water with exhaust steam. The third method is by the injection of live steam into the water-supply pipe.

Gas heaters of the instantaneous type are sometimes used either for an emergency, as at the Norwood Civic Association, or for regularly heating the water. For regular use under usual conditions they are apt to prove expensive to operate.

The temperature may be controlled by hand regulation of the steam valve or preferably by a thermostatic valve working automatically.

Bathing Load. — Several writers have adopted standards for the comparison of the burden placed upon swimming pools. Such a standard may be obtained by dividing the capacity of the pool, in gallons, by the average total number of bathers per week. This standard has been computed as far as possible with the data available for the pools listed in the table. For a number of the pools, the capacity was not given, but has been estimated from the data available.

Rules Concerning Bathers. — Nude bathing is required at many of the pools for men and boys. Where suits are allowed, they are generally furnished by the management or else required to be uniform in style and of fast color and free from lint. The best practice seems to require that suits, when allowed, should be thoroughly washed and sterilized after using, by equipment maintained by the pool management.

At all of the Y. M. C. A. pools and at many of the other non-public pools, physical examinations of the bathers are made from time to time, and in addition, all bathing is done under inspection.

All pools reported requiring a hot shower bath with soap before entering the pool. This rule can be more readily enforced where the shower baths are adjacent to the pool, and especially so where it is necessary to pass through the shower bathroom in order to reach the pool. The importance of the strict enforcement of the bathing rule cannot be exaggerated. That the enforcement of this rule should be a continual source of complaint, even when dealing with well-educated persons of mature age, is surprising, but from all reports appears to be a fact, nevertheless.

Precautions against Accident. — The replies received in regard to this subject indicate that under no conditions should swimming alone in a pool be permitted. It is the practice at most pools to have at least one instructor present, and usually at least three persons. Life preservers should be placed within easy reach and at some pools a call bell is provided to make it possible to summon assistance in case of accident. A pulmotor is considered by some as a necessary part of the equipment. Where steam pipes or radiators are located in the pool or room about the pool, they should be fully protected by guards to prevent bathers being burned. Steps or ladders and handrails should be conveniently located.

The results of this investigation have impressed the writer with the great need of expert inspection and control of swimming pools by some central authority, provided with enforcement powers to make it possible to keep the water of the pools in reasonably good sanitary condition. Studies made at a number of pools have shown how easily the water may be prevented from becoming seriously polluted and a possible source of infection, by proper supervision aided by chemical and bacteriological analyses. Many pool operators are not provided with funds for obtaining such aid. It would seem that the use of swimming pools is becoming so widespread as to call for the protection of the persons using them by providing the required supervision, from public funds. The action of the Rhode Island authorities, as outlined by Mr. Gage, is therefore particularly commendable. It is further believed that an inspection of the small pools or "plunges" in Turkish-bath establishments and clubs would reveal the need of better supervision of the treatment of the water.

Mr. Gage.* — The matter of ultra-violet rays has been mentioned. When using the ultra-violet rays, a small amount of water is carried through the apparatus, sterilized, and mixed with the water in the pool, and the question of the purification is not a simple question of the amount of the bacterial removal by the disinfecting apparatus but a question of the dilution. As I tried to make clear on the diagram, with the usual circulation system it takes four to ten days to obtain purification by dilution and this would also hold true in the case of the violet ray apparatus. With chlorination by hypochlorite, on the other hand, the disinfectant is added directly to the pool and the whole body of water disinfected at one time. With chlorination by chlorine gas, a condition similar to that with the ultra-violet rays, is obtained. That is, a small portion of the water is sterilized and returned to the pool and the purification is therefore a question of dilution.

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* Author's Closure.

There has been quite a little data published to show that this process is effective in destroying bacteria in clear waters, but so far as I know not much has been published as to its use in connection with swimming pools. My criticism was based upon theoretical grounds as I have had no personal experience with violet ray disinfection.

Mr. Percy M. Blake has enquired as to the relative advantages of a stored surface water and a ground water and also as to the amount of chemical treatment which might be required under the two conditions.

A stored surface water would probably run much higher in color than a well water, and when the pool was first filled it would take somewhat longer to get it cleaned up,—that is to get the color of the water down where the pool would appear attractive. Further than that, I do not see that there would be any material advantage in one water over the other. There should not be any physiological difference to the bathers or any appreciable difference in the load on the purification system except in that initial period. Mr. Weston suggests there might possibly be iron in the ground water, and in that case it would be rusty or colored and would have to be filtered to give it a satisfactory appearance, the same as would have to be done with a surface water. Rusty water is one of the serious troubles in refilling a pool from city mains, owing to the rust stirred up in the pipes by the increased velocity of the water. For example, at Newport the city water is so low in color that it could be used for filling the swimming pools without filtration if it was not for the rust that is stirred up when filling.

So far as I can see the hardness of the ground water would not appreciably affect any of the treatments ordinarily applied to swimming-pool waters. As the pool is continued in use, especially if hypochlorite of lime is used as a disinfectant, there will always be a gradual increase in the hardness of the water. The relative increase would be about the same whether you start with a soft surface water or a hard ground water. Unless the pool were continued in use without refilling much longer than is the usual practice, I do not believe this would ever become objectionable.

Bathing in ponds used as sources of water supply has also been brought up. Two or three years ago, we found that a lake used as a source of drinking water for one of our state institutions was being used for bathing. The bathing beach was over a mile from the water-works intake and the number of bathers was small, but we felt that bathing in a pond used as a drinking-water supply was potentially dangerous, and stopped it.

The question of the sanitary aspect is a question of reasonable danger, and we as health officials had to consider that there was a possibiliy of contamination from persons bathing. We know that persons bathing in fresh or salt water in the open are not always as cleanly as they might be, and sometimes use the water for purposes for which it should not be used, and we felt that contamination from this source might be carried by winds and currents across the lake to the water supply. It was a water-supply question, and we had to be on the safe side. As to what degree of pollution might be safe or dangerous to persons bathing I cannot answer the question. As I said, we started to make a study of the outdoor bathing beaches and of the wading pools for children which are to be found in our cities but so far this study has not gone far enough for me to draw any conclusions.

The whole question of bacterial standards which has been mentioned is rather up in the air, even on what limits shall be placed on the bacterial content of water for drinking purposes. I have been accustomed to assume that if a bathing pool is as good bacterially as a good drinking-water supply the bathing pool was entirely safe. This may be setting the standard rather high for bathing water; but we are on the safe side.

The United States public health standard for drinking waters to be used on trains in interstate service requires that B. coli shall not be found in more than " one out of five 10 cc. portions of any sample of the water." A good many think this standard is somewhat stringent, but it is a very good one to apply because it has the backing of the United States Government.

The standard also limits the numbers of bacteria to 100 per cc. In swimming-pool work, however, I have not been accustomed to pay much attention to the total bacteria because we are bothered by aftergrowths. During disinfection we destroy the great majority of the bacteria, probably all of certain kinds, and thus upset the natural bacterial balance of the water. As a result, conditions are favorable for the few remaining bacteria, or for bacteria introduced by bathers, to multiply rapidly, giving us very high counts. So you might have a million bacteria and at the same time the types of bacteria on which we are accustomed to figure your pollution, — might be entirely absent. Under these conditions we would have to ignore the high counts and base our interpretation on other evidence.

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Studies on the Sanitation of Swimming Pools, by W. A. Manheimer. Detailed article on infections traced to pools; references to literature on disinfection and operation; extensive experiments on pools by classes — collegiate, association, public pools, outdoor floating baths, Mikveh plunges for Jewish people; bacterial counts; disinfectants; methods of analysis.

Sci. Am., Vol. III (1914), p. 120.
Sterilizing the Water of Swimming Pools with Ultra-Violet Ray, by M. Von Recklinghausen.

J. Am. Pub. Health, Vol. 4 (1914), pp. 1016–1020.
Study of a Swimming Pool, by J. F. Norton. Conditions at Y. M. C. A., Cambridge; construction, filtration; sulphate of alum and hypochlorite of lime; bacterial counts; nitrite determination best indication of bacterial pollution.

Eng. Rec., Vol. 69 (1914), p. 159.
Purifying Water in Indoor Swimming Pool; results with hypochlorite Y. M. C. A. pool at Cambridge; construction — bacterial counts.

Sci. Am., Vol. III (1914), 9. 43.
Sanitary Swimming Pool, by V. Schmelz.

J. Ind. & Eng. Chem., Vol. 7 (1915), pp. 496–499.
The Use of Copper Sulphate in the Purification of Two Pools, by S. J. Thomas. Treats of infections, disinfectants; use of hypochlorites, also copper sulphate; observations at Taylor Gymnasium, Lehigh University. See also *J. Am. Med. Assoc.*, Vol. LXV (1915), pp. 1104–1105.

J. Am. Med. Assn., (1915).
Sanitation of Swimming Pools.

Ohio Pub. H. J., (1915), p. 670.
The Sanitation of Swimming Pools, — Abst. from Am. Med. Assn.

Sci. Am. S., Vol. 80 (1915), p. 352.
Disinfection of Swimming Pools with Copper Sulphate.

Phys. Training, June, (1916), pp. 314–316.
Care and Sanitation of Swimming Pools, by C. H. Hagenbuch.

Phys. Training, Feb., (1916), pp. 110–115.
The Chlorinator and Suggestions for the Caretaker of a Swimming Pool, by Charles J. Velte.

Eng. News,, Sept. 30, (1915), pp. 634–636.
Swimming Pool Disinfection with Ultra-Violet Rays. Describes and illustrates Athletic Club and West Side Y. M. C. A. pools, N. Y. City where ultra-violet process is used; diagram of pressure type of sterilizer.

U. S. Pub. H. Repts., Vol. 30 (1915), pp. 2796–2811.
Essentials of Swimming Pool Sanitation, by Wallace A. Manheimer. Quality of water improved by dilution; supervision of bathers; re-filtration and disinfection recommended.

J. Infec. Diseases, Vol, 18 (1916), pp. 293–306.
The Sanitary Control of Swimming Pools, by Max Levine. Copper sulphate more efficacious than calcium chloride; filtration; disinfection with copper sulphate and with calcium chloride.

Proc. N. E. Assoc. Chem. Teachers, 56th Reg. Meeting (1916), pp. 22–36.
Address by Frederick Bonnet on "A Problem in Modern Sanitation." Treats in detail of sanitation of swimming pools, infectious diseases; customary construction; operation of tank; treatment of water by filtration, coagulation, disinfection; bacteria and B. coli counts; use of chloride of lime, sodium hypochlorite; method and rate of application of copper sulphate; metallic copper counts in various foods.

El. R. & W. Elec., Vol. 69 (1916), p. 609.
Electric purification of water in swimming pool.

Eng. & Contr., Vol. 46 (1916), pp. 135–136.
Prelim. Report upon Purification of Swimming Pools of State Univ. of Iowa, by J. J. Hinman. Concrete pools lined with enameled brick; operating data; chlorine disinfection.

Concr., Vol. 8 (1916), pp. 147–149.
Construction of Open Air Concrete Pool in Canadian Rockies; structural details, cost data, diagrams and photographs.

Philip. J. Sci., Vol. 11, (1916), pp. 105–122.
Chemical Purification of Swimming Pools, by G. W. Heise and R. H. Aguilar. Chemical treatment of Manila city water with copper sulphate and bleach. Effect of temperature of water and light available. Chlorine-consuming capacity of water best indication of quality and of dosage of disinfectant necessary.

J. Infec. Diseases, Vol. 18 (1916), p. 293.

Eng. & Contr., Vol. 46 (1916), pp. 135–136, J. J. Hinman.
Describes pools at State Univ. of Iowa; structural features; operation; use of aluminum sulphate and liquid chlorine; bacterial counts; illus.

Sci. Am. S., Vol. 82 (1916), p. 246.
Swimming Pool Sanitation.

J. Ind. & Eng. Chem., Vol. 8, (1916), pp. 914–921.
Some features of Swimming-Pool Control, by W. L. Lewis. Relates various infections traced to pools. Desirable construction; disinfection, shower baths, suits; alkalinity and reaction with alum; use of hypochlorite; hardness of water; analyses of pool water; comparison of rotating and intermittent systems of oper.; hypochlorite *vs.* copper sulphate with bacterial counts.

J. Am. W. W., Vol. 4, (1917), pp. 86–103.
Swimming Pool Operation, by J. J. Hinman. Desirable design; shower-bath facilities; dangers of infection; re-filtration, disinfection; method and cost of operation; tabulation of bacterial counts for various pools.

Ohio Public H. J. (1917), pp. 247–251.
The Sanitary Aspects of Swimming Pools, by J. H. Van Buskirk. Infections traced to pools; recommends white tile lining and trough; operating results; disinfection with copper sulphate and bleach; liquid chlorine.

J. Infec. Diseases, Vol. 20 (1917), pp. 1–9.
Comparison of Methods for Disinfecting Swimming Pools, by Wallace A. Manheimer. Efficiency and cost of disinfecting with ultra-violet light, ozone, chlorine, copper sulphate, bleach, etc.; "Lectrocide."

Metal Wk., Vol. 87 (1917), pp. 328–329.
Analysis of Water in Swimming Pool, by J. F. Norton.

Metal Wk., Vol. 88 (1917), pp. 265–267.
Sanitary Aspects of Swimming Pools, by H. St. Van Buskirk.

J. Ind. & Eng. Chem. (1917), Vol. 9, pp. 56–57.
Artificial Alkalinity in Water for Filtration, by J. W. Clark.

Munic. J., Sept. 17, (1917), p. 863.
Swimming Bath Experiments at Manchester. Water aëration and filtration.

Amer. City, Vol. 17 (1917), pp. 237–239.
Chloramine for Water Sterilization, by Jos. Race. Experiments on Ottawa Y. M. C. A. Pool.

Surv., Vol. 46, pp. 26–33.
Continuous Aëration and Filtration of the Water of Public Swimming Baths, by L. H. Lewis. Describes Manchester (England) operating conditions.

U. S. Pub. H. Repts., Vol. 29, p. 12.
Chlorine Treatment of Salt Water Swimming Baths, by W. H. Kellogg.

J. Am. Med. Assoc., Vol. 59, pp. 1424–1425.
The Hygiene of Swimming Pools, by M. P. Ravenel. Exam. of water at Univ. of Wisconsin Bacterial results; calcium hypochlorite. See also *Proc. Sixth Congress*, Am. School Hyg. Asso.

Surv., Vol. 43, p. 283.
Purification of Swimming Baths Water, by Royal San. Inst. Committee. Discusses filtration, aëration and hypochlorite sterilization.

Amer. Phys. Ed. Rev., Vol. VIII, Pt. 2.
The Use of Chloride of Lime in the Purification of Swimming Pools, by S. C. Markley.

Construction.

Arch. Rev., Vol. 22 (1907), pp. 30–35.
Chelsea (Eng.) Public Baths, — photographs, plans, structural details and operating methods.

Brickb. (extra Ed. to No. 2, Vol. 19) (Feb. 1910).
Spec. edit. giving results of public bath and gymnasium competition — some 15 designs, preceded by brief descriptive text.

Eng. News, Vol. 64 (1091), pp. 144–145.
The Carnegie Swimming Pool at Yale Univ., by C. S. Farnham. Describes construction; photograph and structural details.

Eng. Rec., Vol. 65 (1912), pp. 372–373.
Combined Fire Service Reservoir and Swimming Pool at Berkeley, Cal.; photograph of pool and of repairs to concrete floor; describes design and construc.; method of operation and water supply; details of design.

J. Munic. Eng., Vol. 43 (1912), pp. 401–402.
Waterproofing of Swimming Pools, by Linn White; structural data and operating methods of several pools of the So. Park Comn., Chicago; Terra-cotta, lined with ceresit waterproofing.

Brickb., Vol. 22 (1913), p. 127.
Planning a Young Men's Christian Assoc. Building, Pt. III, by Louis A. Abramson; descriptive text, structural details and plan of shower baths and natatoriums.

Eng. News, Feb. 6, (1913), pp. 256–257.
Details of Construc. of Swimming Pool at Rensselaer Polytech. Inst.; design and construction; gives diagram showing structural details.

Dom. Eng., Vol. 69 (1913), pp. 63–65; pp. 126–128; pp. 189–191; pp. 264–266.
Construction of mechanical installations connected with swimming pools; water supply, heating, etc.

Power, Vol. 37 (1913), p. 277.
Boiler Capacity Required to Heat a Swimming Pool, by J. P. Lisk.

J. Munic. Eng., Vol. 47 (1914), pp. 127–128.
Brief description of McKeesport, Pa., public bathing basin — popular article with photograph.

House and Gard., Aug., (1914), pp. 79–81.
The Bathing Pool at the Country House, by R. H. Van Court — popular article describing various pools, desirable design, location, accessories and operation.

Eng. News, Vol. 72 (1914), p. 397.
Open Air Swimming and Wading Pool in Fair Ground Park at St. Louis, Mo. — circular pool with reinforced concr. slab bottom on cinder bed; expansion joints; cost data; plan of pool; details of joints.

The Brickb., Vol. 24 (1914), pp. 135–139.
Bathing Pools within and Out-of-Doors, by Wilfred Carew. Illustrates eight pools and describes desirable construction.

Metal Wk., Vol. 82 (1914), pp. 253–254.
Swimming Pool of Modern Construction at People's Palace, Jersey City, N. J.

Dom. Eng., Vol. 68 (1914), pp. 382–383.
Municipal Swimming Pool, Pasadena, Cal.

Metal Wk., Vol. 82 (1914), pp. 642–643.
Open-Air Swimming Pool at Pasadena.

Build. Age, Vol. 36 (1914), pp. 31–34.
Swimming Pool and Dancing Pavilion in Connection with Country Club at Wichita, Kan.

Dom. Eng., Vol. 70 (1914), pp. 34–35; pp. 101–102.
Mech. installations connected with swimming pools; heating, water supply, etc.

Munic. J. & Eng., Vol. 39 (1915), p. 224.
Salt Water Swimming Pool, Forest River Park, Salem, Mass.; brief description; photograph.

J. Munic. Eng., Vol. 49 (1915), p. 212.
Swimming Pool and Flush Tank Combined at Oakdale, Cal. Dimensions and cost of open concr. pool out-of-doors, built in form of tank; waste water used to flush sewers.

Brickb., Vol. 24 (1915), pp. 13–16, and plates following.
Edit. on public bathing establishments; photographs, plans and details of various pools in American cities.

Brickb., Vol. 24 (1915), pp. 101–102.
South side bathhouse, Pittsburgh, Pa. — views and plans.

Metal Wk., Vol. 84 (1915), pp. 522–523.
Swimming Pool at Pittsburgh Athletic Club.

Metal Wk., Vol. 83 (1915), pp. 796–798.
Wealthy Californian's Pool de Luxe.

Metal Wk., Vol. 84 (1915), pp. 729–730; pp. 837–838.
Plumbing and Heating Details of Plunges.

Metal Wk., Vol. 84 (1915), pp. 605–607.
Plumbing Work in Harvard Club of New York.

Metal Wk., Vol. 83 (1915), pp. 288–290, and *Building Age*, Vol. 37, pp. 39–40.
Plumbing Equipment of Swimming Pool, Louisville, Ky.

Metal Wk., Vol. 83 (1915), p. 727.
St. Louis Builds Large Swimming Pool.

Dom. Eng., Vol. 73 (1915), pp. 134–137.
Natatorium in the Evander Childs' High School, N. Y. City, by E. R. Porter.

Dom. Eng., Vol. 72 (1915), p. 229.
Concrete Natatorium for Chicago School Children.

Build. Age, Vol. 37 (1915), pp. 51–52.
Details of Open-Air Swimming Pool.

Arch. Rec., Vol. 37 (1915), pp. 116–131.
Jn. C. Proctor Recreation Center, Peoria, Ill.; photographs, plans and brief description.

Arch. Rec., Vol. 38 (1915), pp. 171–176.
Swimming Pool at Home of Miss Helen Gould, Irvington, N. Y.; photographs, plans and detailed plates giving dimensions. No text.

Eng. News. Vol. 74 (1915), p. 821.
Municipal Swimming Pool, Grand Rapids, Wis. Brief article; pool situated below dam; fed by continuously running stream; concrete walls, sand bottom, sluice gate.

Conc.-Cem. Age, Vol. 6 (1915), pp. 148–149.
Swimming Pool at Rockledge, Fla.; construction and design; gives details and photographs.

Dom. Eng., Vol. 74 (1916), pp. 391–393.
Information about swimming pools.

Metal Wk., Vol. 85 (1916), pp. 188–189; pp. 350–351; pp. 633–635.
Plumbing and Heating Details of Plunges.

Metal Wk., Vol. 85 (1916), pp. 33–36.
Pullman, Ill., Municipal Swimming Pool — has unique features.

Heat. & Vent., Vol. 13 (1916), pp. 39–40.
Data for figuring an indoor plunge.

Dom. Eng., Vol. 77 (1916), pp. 36–37.
Heating and Plumbing System in a Public Natatorium in Chicago.

Concr., Vol. 8 (1916), pp. 149–150.
Construction of Concrete Swimming Pool at Pendleton, Ore., by L. R. W. Allison. Describes pool; table of construction costs and method of financing.

El. R. & W. Elec., Vol. 68 (1916), p. 464.
Quarter Horse-power Motor Saver of $25 per Month for Swimming Pool.

Dom. Eng., Vol. 77 (1916), p. 289.
Plumbing and heating of new swimming pool at Union League, Club Chicago.

Eng. & Contr., Vol. 44 (1917), p. 357.
Design features of reinf. concrete swimming pool at Riverview Park, Chicago; gives plan and section and table of reinforcement used.

J. West. Soc. C. E., Vol. 22 (1917), pp. 16–35.
Addition to the Union League Club (Chicago), by Fk. E. Brown. Describes construction and gives detailed drawings of pool. (See also *Eng. News*, Vol. 77 (1917), pp. 56–57.

Eng. Rec. (1917), pp. 106–107.
Construction of Swimming Tank in Union League Club, Chicago, — description, plan; details of piers; steel plate construc., lead-lined, membrane waterproofing, ceramic tile.

Dom. Eng., Vol. 80 (1917), pp. 365.
Modern Outdoor Swimming Pools, by J. A. Ward.

Dom. Eng., Vol. 79 (1917), pp. 366–367.
Swimming Pools in Public Schools.

Metal Wk., Vol.. 87 (1917), pp. 701–703.
Swimming Pool heating and filtering plant.

Dom. Eng., Vol. 79 (1917), pp. 47–48.
Roof Swimming Pools Offer Opportunity for More Bathers in Congested Communities.

Elec. W., Vol. 69 (1917), p. 470.
Lighting swimming pool with submerged lamps. Pool at Seattle, Wash. Brief article, with cross-section of lighting unit.

Concr., Vol. 10 (1917), pp. 181–183.
Design of Pools Built of Concrete. Protection against frost, proper foundation; water-tightness; three illustrations of pool; design of typical pool.

Harding & Willard — Mechanical Equipment of Buildings 1916, 1st Ed., Vol. I, p. 181.
Methods of heating water; steam and boiler horse-power required; area of steam coils and connections necessary.

Abbreviation.	Title.
Amer. City	American City.
Am. J. Pub. Hyg.	American Journal of Public Hygiene.
Am. Phys. Ed. Rev.	American Physical Educational Review.
Am. Med	American Medicine.
Arch. Rec.	Architectural Record.
Arch. Rev.	Architectural Review.
Assn. Mun. & Cty. Eng.	Association of Municipal and County Engineers.
Boston Med. J.	Boston Medical Journal.
Brickb.	Brickbuilder.
Build. Age	Building Age.
Concr.	Concrete.
Conc.-Cem. Age	Concrete-Cement Age.
Dom. Eng.	Domestic Engineering.
El. R. & W. Elec.	Electrical Review and Western Electrician.
Elec. W.	Electrical World.
Eng. & Contr.	Engineering and Contracting.
Eng. News.	Engineering News.
Eng. Rec.	Engineering Record.
Gsndhts. Ing.	Gesundheits Ingenieur.
Heat. & Vent.	Heating and Ventilating Magazine.
House & Gard.	House and Garden.
Hyg. Runds	Hygienische Rundschau.
J. Am. Med. Assoc.	Journal of the American Medical Association.
J. Am. Pub. Health	Journal of the American Public Health Assciation.
Jour. Am. W. W.	Journal of the American Water Works Association.
J. Ind. & Eng. Chem.	Journal of Industrial and Engineering Chemistry.
J. Infec. Diseases	Journal of Infectious Diseases.
J. West. Soc. C. E.	Journal of the Western Society of Civil Engineers.

Abbreviation.	Title.
Mass. St. Bd. Health	Massachusetts State Board of Health.
Metal Wk.	Metal Worker, Plumber and Steam Fitter.
Munic. Eng.	Municipal Engineering.
Munic. J. & Eng.	Municipal Journal and Engineer.
Ohio Pub. H. Jour.	Ohio Public Health Journal.
Philip. Bur. Sci.	Philippine Bureau of Science.
Phys. Training	Physical Training, published by Physical Directors' Society of the Young Men's Christian Associations of North America.
Power	Power.
Proc. Am. Assn. Prom. Hyg. & Pub. Baths	Proceedings of the American Association for the Promotion of Hygiene and Public Baths.
Proc. Ill. Wa. Sup. Assn.	Proceedings of the Illinois Water Supply Association.
Proc. Ind. San. Wa. Sup. Assn.	Proceedings of the Indiana Sanitary and Water Supply Association.
Proc. N. E. Assoc. Chem. Teachers	Proceedings of the New England Association of Chemistry Teachers.
Rept. Med. Officer Loc. Gov. Bd., Eng.	Report of the Medical Officer of the Local Government Board, England.
Sci. Am.	Scientific American.
Sci. Am. S.	Scientific American Supplement.
Surv.	Survey.
Thomp. Yates Lab. Repts.	Thompson Yates Laboratory Reports.
U. S. Pub H. Repts.	U. S. Public Health Reports.

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PAPERS AND DISCUSSIONS

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DISCUSSION OF ECONOMY IN THE DESIGN OF CONCRETE BUILDINGS.

By Frank S. Bailey, J. R. Worcester, Leslie H. Allen, Burtis S. Brown, John R. Nichols.

Frank S. Bailey.* — The writer has been considerably interested in Mr. Mayer's paper. In computing the unit costs of concrete of 1 : 1½ : 3 and 1 : 1 : 2 mixes, Mr. Mayer uses the same amount of aggregate as he did in figuring the cost of the 1 : 2 : 4 mix and simply adds the cost of the increased quantity of cement. This is a common custom. It may be of interest to know what the difference is in the cost of the different mixes, if allowance is made for the diminished amounts of aggregate in the richer mixes. Computations of the cost of different mixes, using Mr. Mayer's unit prices, and taking the quantities of cement, sand and gravel from Taylor and Thompson's "Concrete Costs," page 151, for average conditions, give results shown in Table 1.

It is of interest to note that the cost of the 1 : 2 : 4 and 1 : 1½ : 3 mixes is about 5 per cent. more by the customary method than by Taylor & Thompson's figures, and about 9 per cent. more for the 1 : 1 : 2 mix; the usual method being slightly unfavorable to the richer mix.

It may be suggested that in designing columns it is well to follow the rule of trying first a concrete mix of 1 : 1 : 2 with 1

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TABLE 1.

		Cost of Concrete per Cu. Ft.		Per Cent. Increase of Mayer's.
		T. & T. tables.	Mayer.	
1 : 2 : 4 mix.				
1.57 bbl. cement at $2	$3.14			
.44 cu. yd. sand at $1.50	.66			
* 1 205 tons broken stone at $2	2.41			
Plant, mixing and placing	2.50			
Total cost per cu. yd.	$8.71	$0.323	.34	5.3
1 : 1½ : 3 mix.				
2.00 bbl. cement at $2	$4.00			
.42 cu. yd. sand at $1.50	.63			
* 1 135 tons broken stone at $2	2.27			
Plant, mixing and placing	2.50			
Total cost per cu. yd.	$9.40	.348	.365	4.9
1 : 1 : 2 mix.				
2.73 bbls. cement at $2	$5.46			
.38 cu. yd. sand at $1.50	.57			
* 1.04 tons broken stone at $2	2.08			
Plant, mixing and placing	2.50			
Total cost per cu. yd.	$10.61	.393	.43	9.4

* 20 cu. ft.=1 ton.

per cent. of vertical steel, in square or rectangular columns, and the same mix and ratio of vertical steel with 1 per cent. of steel spirals for round columns; then, if the right ratio of length to diameter of column is not exceeded, and there are no bending moments to be considered, comparisons with other mixes or steel ratios are needless, as none will show greater economy. It is well known that it is more economical to use a low ratio of steel for compression where saving in space is not a factor, and Mayer's figures show that this fact holds true when ordinary values are allowed for space saved by using more steel. Table 2 shows the relative economy of the three mixes in columns without spiral hooping.

TABLE 2.

Showing Comparative Costs per 100 000 Lbs. Compressive Strength of Different Mixes of Hard Sandstone Concrete, Using Joint Committee's Values for Compression and Mayer's Cost Figures.

Mix.	Compressive Strength. Lbs. per Sq. In.	Lbs. per Sq. Ft.	Cost per Cu. Ft.	Cost per 100 000 Lbs. Compressive Strength.
1 : 2 : 4	450	64 900	$0.34	$0.525
1 : 1½ : 3	563	81 000	0.365	0.450
1 : 1 : 2	675	97 200	0.43	0.442

Note. Where large bending moments exist in columns, the conditions of stress are analogous to those in a beam, and it is possible that in some cases a 1 : 2 : 4 mix will compare favorably as to cost with the 1 : 1 : 2.

The same relative economy for the 1 : 1 : 2 mix at prices prevailing ten years ago is shown in the following tables, in which the cost figures are taken from a paper by Mr. L. C. Wason, member of Boston Society of Civil Engineers, on "Proportioning and Mixing Cement Mortars in Concrete," which was printed in the Proceedings of the National Association of Cement Users for 1908.

TABLE 3.

Showing Comparative Costs per 100 000 Lbs. Compressive Strength of Broken Stone Concrete.

(Based on prices for the year 1908.)

Concrete Mix.	Compressive Stress (Joint Committee Values for Hard Limestone). Lbs. per Sq. In.	Lbs. per Sq. Ft.	Cost per Cu. Ft. of Concrete.	Comparative Cost per 100 000 lbs. of Compressive Strength.
1 : 2 : 4	450	64 900	$0.264	$.408
1 : 1½ : 3	562.5	81.000	.283	.350
1 : 1 : 2	675	97 200	.314	.323

TABLE 4.

Showing Comparative Costs per 100 000 Lbs. Compressive Strength of Gravel Concrete.

1 : 2 : 4	450	64 900	$0.214	$0.330
1 : 1½ : 3	562.5	81 000	.237	.293
1 : 1 : 2	675	97 200	.274	.282

Costs in Tables 3 and 4 based on following constants:

Cement delivered on job, per barrel, net	$1.75
Broken stone (21 cu. ft. = 1 ton) per ton	1.50
Sand, per cu. yd.	1.20
Gravel (containing stone and sand in right prop.) per cu. yd.	1.15
Labor (foreman, common and miscellaneous), $0.06 per cu. ft. or per cu. yd.	1.62

It is therefore apparent that the 1:1:2 mix is the most economical of the three for furnishing uniform compressive strength in columns; and, if the cost figures of Table 1 are used, there is shown a still greater relative economy for this mix. It is also evident that the 1 : 1 : 2 mix is the more economical to use for compressive strength in columns with spiral hooping, as the ratio of increases in allowable stress is the same for each mix, and there is a slight advantage for the richer mix from the fact that a smaller section can be used, thus requiring less spiral steel.

The following tables have been prepared to show the approximate relative costs of beams or slabs of various concrete mixes, when the bending moment is the controlling factor in determining the section.

TABLE 5.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF BEAM OR SLAB OF DIFFERENT MIXES OF CONCRETE, WITH STRESS IN STEEL 16 000 LBS. PER SQ. IN.

Mix.	Cost of Concrete per Lin. Ft. of Beam.	Cost of Steel per Lin. Ft. of Beam.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	0.000236\sqrt{Mb}$	0.000154\sqrt{Mb}$	0.000390\sqrt{Mb}$
1 : 1½ : 3	0.000218$\sqrt{Mb}$	0.000140$\sqrt{Mb}$	0.000358$\sqrt{Mb}$
1 : 2 : 4	0.000226$\sqrt{Mb}$	0.000125$\sqrt{Mb}$	0.000351$\sqrt{Mb}$
1 : 2½ : 5	0.000256$\sqrt{Mb}$	0.000103$\sqrt{Mb}$	0.000359$\sqrt{Mb}$

TABLE 6.

SHOWING APPROXIMATE COST PER LINEAR FOOT OF BEAM OR SLAB OF DIFFERENT MIXES OF CONCRETE, WITH STRESS IN STEEL 18 000 LBS. PER SQ. IN.

Mix.	Cost of Concrete per Lin. Ft. of Beam.	Cost of Steel per Lin. Ft. of Beam.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	\$0.000242$\sqrt{Mb}$	\$0.000131$\sqrt{Mb}$	\$0.000373$\sqrt{Mb}$
1 : 1½ ; 3	0.000226$\sqrt{Mb}$	0.000120$\sqrt{Mb}$	0.000346$\sqrt{Mb}$
1 : 2 : 4	0.000234$\sqrt{Mb}$	0.000106$\sqrt{Mb}$	0.000340$\sqrt{Mb}$
1 : 2½ : 5	0.000265$\sqrt{Mb}$	0.000089$\sqrt{Mb}$	0.000354$\sqrt{Mb}$

Tables 5 and 6 were computed by the following method.

For a given quality of concrete and steel in a beam or slab the depth to the steel may be expressed by the formula $d=C\sqrt{\frac{M}{b}}$,

in which M = Bending moment in inch lbs.

b = Breadth of beam or slab in inches.

C = A constant (for a given combination of concrete and steel).

Values of C for different stresses in concrete and steel are given on page 483 of the third edition of "Concrete, Plain and Reinforced," by Taylor and Thompson. Concrete stresses for different mixes are those recommended by the Joint Committee for concrete with hard sandstone aggregate, and costs are Mr. Mayer's figures.

To illustrate, take the 1:1:2 mix in Table 5; $d=0.079\sqrt{\frac{M}{b}}$.

Then, cubic feet of concrete per linear feet of beam =

$$\frac{0.079\sqrt{\frac{M}{b}}\times b\times 12}{1728},$$

and the cost of concrete per linear foot of beam is found by multiplying the latter expression by \$0.43, and equals \$0.000236$\sqrt{Mb}$.

The sectional area of steel, in this case, $=0.0115\times 0.079\sqrt{\frac{M}{b}}\times b$.

Its weight per linear ft. $=0.0115\times 0.079\sqrt{\frac{M}{b}}\times b\times 3.4$, and the cost per linear ft. = the latter expression multiplied by \$0.05 and equals \$0.000154$\sqrt{Mb}$.

These figures do not include the cost of concrete in the beam below the steel, nor the cost of forms, but they give a good general idea of the relative costs of various combinations, for a simple beam or slab of one span, with no steel in the top of beam over the supports, and the breadth remaining constant.

To arrive at the comparative costs of continuous slabs which have the same amount of steel over the supports as there is in the center of the span, and half this amount in the bottom of slab at the supports, the quantities, and therefore the costs, of the steel as given in Tables 5 and 6 should be increased 25 per cent. The effect of this increase is shown in Tables 7 and 8.

TABLE 7.

Showing Approximate Cost per Linear Foot of Continuous Slab of Different Mixes of Concrete. Steel Stress 16 000 Lbs. per Sq. In. (Steel costs increased 25 per cent. to allow for laps.)

Mix.	Total Cost per Lin. Ft. of Slab.
1 : 1 : 2	\$0.000428$\sqrt{Mb}$
1 : 1½ : 3	0.000393$\sqrt{Mb}$
1 : 2 : 4	0.000382$\sqrt{Mb}$
1 : 2½ : 5	0.000385$\sqrt{Mb}$

TABLE 8.

Showing Approximate Cost per Linear Foot of Continuous Slab of Different Mixes of Concrete. Steel Stress 18 000 Lbs. per Sq. In. (Steel costs increased 25 per cent. to allow for laps.)

Mix.	Total Cost per Lin. Ft. of Slab.
1 : 1 : 2	\$0.000406$\sqrt{Mb}$
1 : 1½ : 3	0.000376$\sqrt{Mb}$
1 : 2 : 4	0.000366$\sqrt{Mb}$
1 : 2½ : 5	0.000376$\sqrt{Mb}$

The additional amount of steel in continuous beams due to laps and stirrups varies in different beams but rarely exceeds 40 per cent. of the amounts used in Tables 5 and 6. The effect of a 40 per cent. increase is shown in Tables 9 and 10.

TABLE 9.

Showing Approximate Cost per Linear Foot of Continuous Beam of Different Mixes of Concrete. Steel Stress 16 000 Lbs. per Sq. In.
(Steel costs increased 40 per cent. to allow for laps and stirrups.)

Mix.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	$\$0.000452\sqrt{Mb}$
1 : 1½ : 3	$0.000414\sqrt{Mb}$
1 : 2 : 4	$0.000401\sqrt{Mb}$
1 : 2½ : 5	$0.000400\sqrt{Mb}$

TABLE 10.

Showing Approximate Cost per Linear Foot of Continuous Beam of Different Mixes of Concrete. Steel Stress 18 000 Lbs. per Sq. In.
(Steel costs increased 40 per cent. to allow for laps and stirrups.)

Mix.	Total Cost per Lin. Ft. of Beam.
1 : 1 : 2	$\$0.000425\sqrt{Mb}$
1 : 1½ : 3	$0.000394\sqrt{Mb}$
1 : 2 : 4	$0.000382\sqrt{Mb}$
1 : 2½ : 5	$0.000390\sqrt{Mb}$

The figures for costs of continuous slabs (see Tables 7 and 8) may be said to represent the actual differences in cost of constructing slabs of the various mixes shown, as the cost of forms is the same in each case and the difference in cost of concrete in bottom of slab below steel is so slight that it is practically negligible. The 1 : 2 : 4 mix is evidently the proper one to use in cases where the bending moment determines the section.

The figures for costs of continuous beams (Tables 9 and 10) must be corrected as shown in the following example.

Assume the width of beam is 12 ins., and depth of concrete below center of steel is 3 ins., and the figures to be corrected are those of Table 9. For the 1 :1 :2 mix the cost per linear foot of concrete below steel is $0.25\times\frac{b}{12}\times\$0.43$ and equals $\$0.009\times b$. The cost of forms is $\left[(0.079\sqrt{\frac{M}{b}}+3)\times 2+b\right]\times\frac{12}{144}\times\$0.16$, which reduces to $\$0.00211\sqrt{\frac{M}{b}}+\$0.08+\$0.0133\times b$. Now, assuming a bending moment of 1 000 000 in. lbs., it will be found that the cost of steel and concrete above steel is \$1.56 per lin. ft., concrete below steel is \$0.11, and forms are \$0.85, the total being \$2.52 per lin. ft. The total costs of the other mixes, in the order given in the table, are respectively, \$2.42, \$2.45 and \$2.60, the 1 : 1½ : 3 mix showing slightly better results than the 1 : 2 : 4 in this particular case, in which it is assumed that the bending moment determines the beam section. In case the section had to be increased on account of shear the results would be different and would depend on whether width or depth or both were increased. Under some conditions, where the section is governed by shear, a 1 : 1 : 2 mix might prove the more economical. In T-beams the stem section is frequently determined by shear, so in such beams it may happen that a 1 : 1 : 2 mix will be better for the stem, and a 1 : 2 : 4 for the flange.

It will be noted that in the above comparisons of cost it has been assumed that the breadth of the beam or slab is constant for all mixes while the depth varies. In cases where the same clear head room must be maintained, it is apparent that the richer mixes have an advantage due to their lesser depth which effects a saving in the height of columns and sometimes in the facing of exterior walls, which should be taken into account in making a final comparison of different designs. If for any reason it is necessary to have the depths of beams remain constant while the breadths vary, or to maintain a certain ratio of breadth to depth, it will be found that the choice as to economy will, at present prices, usually be between the 1 : 1 : 2 and the 1 : 1½ : 3 mixes.

Considering the fact that the prices of cement, sand, stone, gravel, steel and lumber, as well as labor, are constantly changing, it is doubtless impossible to devise a simple formula for determining the most economical mixes for the different parts of a structure. Those which are best for one building at one time may not be the most satisfactory for another similar building at another time. On the other hand, it is doubtless possible after preparing a fairly satisfactory design, to spend more time and money in an attempt to improve it than can be saved in material and labor when it comes to construction.

There are many firms of engineers and architects who prepare plans for buildings to be built by contract. They do not know what contractor will do the work, and sometimes they are not sure that they themselves will have supervision of the construction. Under these conditions they may not think it best to specify the use of different mixes of concrete for different parts of the superstructure. In many cases, the 1 : 2 : 4 or the 1 : 1½ : 3 mix is more economical for beams and slabs than the 1 : 1 : 2, and they may feel that it is safer to specify the use of 1 : 2 : 4 or 1 : 1½ : 3 concrete in beams, slabs and columns.

An engineering firm which maintains a reliable construction force might, on the other hand, feel no hesitation in specifying a richer mixture of concrete for columns, as in its case there is less liability of batches of 1 : 2 : 4 concrete being placed where 1 : 1 : 2 was called for.

In conclusion, the writer would say that he believes Mr. Mayer's paper is worthy of careful reading by any one interested in the subject.

J. R. Worcester.* — This paper is very timely in its suggestions and helpful in its information as to costs, particularly of those items of cost which an engineer not directly interested in construction finds it most difficult to ascertain, such as labor and cost of plant.

It may be worth while to point out, however, that the author has in one of his examples, presented figures which might be misleading if taken as too generally applicable. This is the table of comparative costs of seven different types of columns, pages 65 and 66.

The author does not state the capacity which this column is designed to carry, or the specifications by which it is designed, but the intention is evidently to make the different schemes of equivalent strength. This is not the result, if we follow the rules of the Joint Committee. According to these, scheme (f), which appears to be the cheapest, is not allowable because the longitudinal reinforcement is less than one per cent. of the area. Again, the other schemes, including spiral reinforcement (d) and (g), have about 40 000 lbs. capacity in excess of the types having no spirals. To bring them to the same basis of strength, four longitudinal bars could be left out in (d) and eight 1-in. bars could be substituted for the ten $1\frac{1}{8}$-in. bars in (g). These changes would reduce the cost of (d) to $66.77, and that of (g) to $65.99. The cost of (g) would therefore appear to be less than that of the (f) design, which is not allowable, and makes it appear that in this instance, at least, where allowance is made for the value of the space occupied, the smallest design is preferable.

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* J. R. Worcester & Co., Consulting Engineers, 79 Milk Street, Boston, Mass.

LESLIE H. ALLEN.* — The reason for the apparent difficulty in comparing the costs of the different designs of reinforced concrete is due to the fact that there are so many variables to be taken into account. This is not the case in designing steel structures, as the only variables are the weights and prices of steel. In the case of reinforced concrete we have the labor and materials on concrete forms and reinforcement, and variations in stresses due to changes in the mix and the percentage of reinforcement. For this reason this subject as a rule is a rather difficult one for the consulting engineer.

Following Mr. Mayer's thought a little further, I might suggest that in some buildings recently designed by engineers we figured with them an interesting saving in design in the case of a building which carried different loads on different floors. It was found that by changing the mix of the concrete in the floors it was possible to keep the size of the beams the same on each floor, although the loads changed. The result was that on some floors we built beams and slabs that would not be economical if the same design was carried right through, but on account of the great saving in form work due to the avoidance of any re-making the whole building was a good deal more economical than would have been the case if each floor had been designed for the same mix.

BURTIS S. BROWN.* — I think we are indebted to Mr. Mayers to-night for giving us this paper. Not many years ago we could hardly pick up an engineering magazine without seeing presented some new formula for the economical design of concrete. In nearly every number that came out some one would present a formula on economical design. With so many changeable factors entering into the economical design of concrete, one can see how absolutely impossible it is to incorporate them into a single formula. I think the principal value of this paper is that it educates the engineer's judgment in the design of concrete so that very soon, after figuring out a few of the designs, he is able to spot the most economical one without very much calculation of the special principle.

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* Consulting Engineer, 88 Broad Street, Boston, Mass.

One thing that I think has to be considered where one is designing for a special organization is that that organization can take care of one type of construction more economically than another type. I remember, at one of the meetings of the American Society of Civil Engineers, I discussed with the general superintendent of one of the largest concrete construction companies in the country the question of flat-slab design, and he said that their company could build beam and girder floors even for heavy loads, much cheaper than flat-slab floors. They were better equipped to take care of that type of construction than they were the flat-slab type which some of the Boston specialists were using. There are those special conditions that must be considered and that the general practitioner has to think of, which a concern that is built up to handle a special type of construction does not have to think of so often.

In working out the most economical design of beams, it has been my practice to try several different depths of beams in order to make sure I am getting the most economical beam for each different layout, and I might say in one of my jobs that by studying ten different layouts I was able to get a design that saved fifty thousand dollars over the design first proposed by the people who were intending to build the structure.

John R. Nichols.* — I want to endorse what Mr. Mayers has said about the necessity of making engineering designs, and it is a great pleasure to find one's own ideas so corroborated.

The thing that struck me most emphatically was something to the effect that the design of a window is of prime importance. "Prime" is the right word to use. Not more than five years ago the steel sash companies would make us a window to fit any opening and with glass cut to any size whatever. But within the last five years that has all been done away with and they now issue their catalogues showing certain standard sizes of sash. The design of a window for the opening has a great deal of influence on the cost of the building. I have some tables here of steel sash sizes, and I have picked out a window, the only one that fits a 17-ft. 6-in. bay. That is the smaller window of the two Mr. Mayers has used, and it uses 12-in. glass and has five units, which means it has four mullions. Each mullion costs two or three dollars, depending on the length, and the use of 12-in. glass means that you have a large number of muntins. What I am getting at is that the use of a large number of mullions and the use of small glass means expensive sash. If he increased his window size to 17 ft. 6 in. he can use 16-in. glass with three units, and there he has saved quite a lot of muntin and a whole mullion. If he cut it down, on the other hand, to 17 ft. 4 in. he can use 16-in. glass and only two mullions. This is using United Steel sash. Other makes give a different variation in the sizes, but the principle is the same. The point is this: When you are designing a building, and considering the center-to-center distance between columns, the thing to pick out first is the window you want to use. Then design your column. If you want to get the sash quickly, and the height is determined, and you have got to use 20-in. high glass, in case you wish to use just twelve feet in height you have got to use ten lights. The nearest thing in other sizes is 18-in. glass, eight lights high. Some makers of glass will give you quicker delivery on 14-in. by 20-in. glass size than on 16-in. by 20-in. Thus we see that the design of a window is really of prime importance.

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* With Monks & Johnson, Boston, Mass.

Another matter of importance is the floor space occupied by the exterior column. It doesn't look as though the exterior column occupies a great deal of floor space, but those engineers who have to do with heating these buildings have to run pipe coils by those windows, and don't like to bend every pipe coil around those columns, but like to keep them flush with the wall. There the floor space occupied by wall columns is again a very important feature.

One of the most bewildering unit costs that comes to the engineer in the comparison is the cost of forms when they are to be used once, or where used two or three or four or five times. In many cases, — when we design a boiler house, for instance, — that is only one slab, the roof, and when that is poured the forms are just lumber. I take it that the thirteen or fourteen cents given here wouldn't apply to such cases. On the other hand, I have known of flat-slab forms being used over and over again, and those using them have stated that they cost somewhere near six, seven, or eight cents per square foot. That element is one of the most difficult to deal with in making comparisons of this nature.

MR. MAYERS.*—The cost of forms as I have tabulated them in the paper is based on the ordinary construction of buildings five or six stories high, using them probably three times. The cost of forms when used in a building like that, if used three times, the material cost of one board foot is really used in the unit cost of the forms. The amount of form lumber actually used per square foot of contact surface may be taken at three board feet. Thus, when forms are used but once, it is necessary to estimate on three board feet of material instead of one board foot, as would be the case when forms are used over three times. In the boiler house roof form cost you would have to add to the units in the paper the cost of about two board feet of form lumber, but your salvage would be much more for the lumber where it had been used only once. Generally speaking, if forms are used only once I should figure at least two board feet of lumber more per square foot of surface measurement. I might say, however, that in the comparative costs it would not make much difference what price you used. You have to know more about the conditions and more about the unit costs to price the work for estimating the actual costs. I have been careful to state that those unit costs would not do for use in making an estimate.

Throughout the paper under discussion, stress has been laid on the fact that these designs are of value only in so far as they are representative of quantities of material on which to make comparative estimates for the sole purpose of illustrating the methods of estimating concrete work. Designs were selected which contained various percentages of reinforcement and various mixes of concrete, and are given here in order to illustrate the methods of estimating costs only. The computations for the various designs have been in most cases purposely omitted, as it is the author's intention to have the reader of the paper concentrate his attention on the methods of estimating the cost of the work. If these designs had been given in detail it is quite probable that the paper would lose much of its force as an exponent of estimating methods, as it would then offer an excellent opportunity for an engineering discussion instead of a discussion on the principles of comparative cost estimating.

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*Author's closure.

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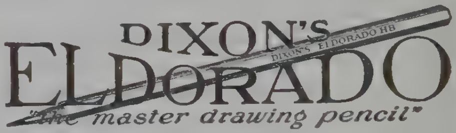

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